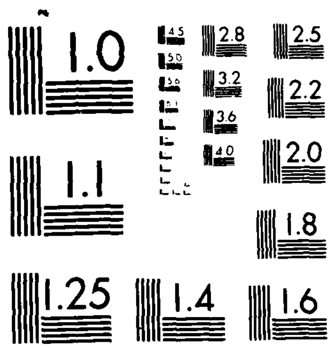
AD-A163 074 PERSON COMPUTER DIALOGUE: A HUMAN ENGINEERING DATA BASE 1/2
SUPPLEMENT(U) ESSEX CORP WESTLAKE VILLAGE CA HUMAN
FACTORS AND TRAINING SYS B E SHAW ET AL. JAN 85
UNCLASSIFIED AFAMRL-TR-85-013 F33615-82-C-0513 F/G 9/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

(12)

AFAMRL-TR-85-013

PERSON COMPUTER DIALOGUE: A HUMAN ENGINEERING DATA BASE SUPPLEMENT

BRIAN E. SHAW
MICHAEL E. McCAULEY, Ph.D.

ESSEX CORPORATION

JANUARY 1985

Approved for public release; distribution is unlimited.

AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6573

NOTICES

TECHNICAL REVIEW AND APPROVAL

AFAMRL-TR-85-013

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
Air Force Aerospace Medical Research Laboratory

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

AD-A163 074

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFAMRL-TR-85-013
6a. NAME OF PERFORMING ORGANIZATION Essex Corporation, Human Factors & Trng Systems Group 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION AAMRL/HEA
6c. ADDRESS (City, State and ZIP Code) 741 Lakefield Road, Suite B Westlake Village CA 91361	7b. ADDRESS (City, State and ZIP Code) Wright-Patterson AFB OH 45433-6573
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-82-C-0513
8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
62202F	7184	26	06

11. TITLE (Include Security Classification)
SEE REVERSE

12. PERSONAL AUTHOR(S)
Shaw, Brian E.; McCauley, Michael E.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Technical	FROM ______ TO ______	1985 January	144

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Dialogue Design Structure, Software Development, Person Computer Dialogue, Interactive Dialogue, Person Computer Interface (Continued)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report was prepared as a Human Engineering Data Base Supplement to the Integrated Information for Designers (IPID) Engineering Data Compendium. It was specifically written to aid computer system designers. The body of literature on person-computer dialogue has been gathered and organized into an integrated format. Major topic areas include conceptual comparisons of person-computer dialogue, models for evaluation of dialogue systems, unique considerations of specific user groups, and specific user-system dialogue design considerations. These major areas are subdivided into succinct discussions of highly focused design considerations. Each discussion of design considerations includes a general description, statement of applications, constraints, and key references in additio to the graphic/tabular formatted design guidelines. An extensive bibliography of literature on person-computer dialogue is included.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☒ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
Kenneth R. Boff, Ph.D.	(513) 255-7596	AAMRL/HEA

DD FORM 1473, 83 APR   EDITION OF 1 JAN 73 IS OBSOLETE.

SECURITY CLASSIFICATION OF THIS PAGE

11. Title

PERSON COMPUTER DIALOGUE: A HUMAN ENGINEERING DATA BASE SUPPLEMENT (U)

18. Subject Terms (Cont'd)

Dialogue Languages;	Design Guidelines,	Data Entry,
User Performance;	User System Interface,	Models.
Human Factors,		

PREFACE

This report was prepared as a supplement to the Engineering Data Compendium being developed under the Integrated Perceptual Information for Designers (IPID) project. IPID is concerned with the consolidation and technical presentation of perceptual and human performance data to enable their use as an effective resource by designers of simulators and operational displays and controls. It is a multi-agency effort supported by the Air Force, Army, Navy and NASA and is managed by the Air Force Aerospace Medical Research Laboratory at Wright-Patterson AFB.

The pertinent research literature contains a staggering volume of potentially valuable human performance data and principles that have not been systematically considered for systems design. Early in the IPID project, the domains of sensation, perception, human information processing and performance were reviewed with respect to their potential value to control and information display design. Forty-five technical subareas were then selected for detailed treatment in a Handbook of Perception and Human Performance. These subareas were authored by some 65 recognized subject-matter experts. The handbook is to be published in early 1986 by John Wiley and Sons as a two-volume work of approximately 3000 pages. The information in the Handbook was organized so that it would be amenable to distillation into specialized data abstracts or entries for consolidation into an Engineering Data Compendium. The emphasis of the Compendium is on a usable presentation of behavioral data to design engineers.

In addition to the basic research topics covered by the Handbook, the following areas of investigation were reviewed by subject-matter experts to identify useful data for extending the range of the Compendium to the applied research domains:

- Information coding, portrayal and format
- Target detection, recognition and identification
- Automation and allocation of functions
- Person-computer dialogue
- Feedback, warning and attentional directors
- Human performance reliability
- Controls
- Vibration and visual displays

This report on Person-Computer Dialogue has been produced as a separate volume from the Compendium to enable its early dissemination to computer systems designers. Timeliness seemed especially critical given the rapidly changing state of knowledge and technology in this domain.

This work was performed by Essex Corporation through a contract with MacAulay-Brown, Inc. under Air Force prime contract F33615-82-C-0513. Dr. Kenneth R. Boff was the Air Force Aerospace Medical Research Laboratory Program Manager. Mr. Gian Cacioppo was the Program Manager with principal support by Ms. Judy Williams for MacAulay-Brown, Inc. The Essex Corporation Program Manager was Mr. Clarence A. Semple. Dr. Michael E. McCauley was the Essex Principal Investigator for this project.

This work was accomplished under AFAMRL Human Engineering Division Project 7184, Task 26, Work Unit 06. The Program is grateful to Mr. Charles Bates, Jr., HE Division Chief and to Dr. Thomas Furness III, Branch Chief, for their support. This effort was partially supported by funds from the Air Force Deputy for Simulators, ASD/YW. We are indebted for this sponsorship to Mr. Art Doty and Mr. Jim Basinger, ASD/YWE, and Mr. George Dickison and Ms. Nancy Droz, ASD/YWB. Ms. Gloria Calhoun, AFAMRL/HEA, and Dr. Janet Lincoln, New York University, made vital contributions to the success of this effort during its initial phases. Dr. Hershel Self, AFAMRL/HEA, and Dr. Edward A. Martin, ASD/ENETS, carefully reviewed and commented on the manuscript. Administrative assistance was provided by Tanya Ellifritt, AFAMRL/HEA.

The authors wish to express appreciation to the following consultants who provided valuable information and advice within a very limited time schedule: Drs. Stuart Card and Thomas Moran of XEROX Palo Alto Research center; Dr. Michael Danchak of the Hartford Graduate Center; and Ms. Beverly Williges of Virginia Polytechnic Institute and State University.

Lois Graelis provided extraordinary support as the Essex librarian. Finally, our thanks to Mrs. Joan Funk for her talent and dilligent performance in editing and word processing.

TABLE OF CONTENTS

		Page
	INTRODUCTION	9
1.	STEPS IN PERSON-COMPUTER DIALOGUE DESIGN	13
2.	BASIC PROPERTIES OF PERSON-COMPUTER DIALOGUE	16
3.	COMPARISON OF APPROACHES TO PERSON-COMPUTER DIALOGUE	20
4.	MAJOR DATA MODELS IN DATA BASE SYSTEMS	25
5.	TECHNIQUES FOR MODELING INTERACTIVE SYSTEMS	28
6.	KEYSTROKE MODEL FOR PREDICTING TASK EXECUTION TIME	32
7.	A PROTOCOL ANALYSIS FOR DOCUMENTING USER PROBLEMS WITH INTERACTIVE SYSTEMS	36
8.	FORMAL LANGUAGE AS A DESIGN TOOL FOR PERSON-COMPUTER DIALOGUE	40
9.	PLAYBACK METHODOLOGY FOR EVALUATING PERSON-COMPUTER DIALOGUE	44
10.	INTERFACE DESIGN PRINCIPLES DERIVED FROM HUMAN ERROR ANALYSES	48
11.	TAXONOMY OF COMPUTER-USER CHARACTERISTICS	52
12.	DESIGNING FOR THE CASUAL OR INFREQUENT COMPUTER USER	54
13.	SYSTEM RESPONSE TIME AND THE EFFECT ON USER PERFORMANCE AND SATISFACTION	57
14.	INFORMATION BANDWIDTH IN PERSON-COMPUTER DIALOGUE	62
15.	DESIGN RECOMMENDATIONS FOR QUERY LANGUAGES	65
16.	COMPARISON OF QUERY LANGUAGES: QUERY-BY-EXAMPLE, SEQUEL, AND ALGEBRAIC LANGUAGE	69
17.	DATA ENTRY DISPLAYS	73
18.	COMPARISON OF INPUT TIME AND ERRORS BETWEEN POINT-IN AND TYPE-IN DATA ENTRY	76

TABLE OF CONTENTS (Cont.)

		Page
19.	SEQUENCE CONTROL IN PERSON-COMPUTER DIALOGUE	80
20.	ERROR RECOVERY IN PERSON-COMPUTER DIALOGUE	84
21.	DESIGN AND CONTROL OF CURSORS	86
22.	ON-LINE DOCUMENTATION	88
23.	AIDS TO PERSON-COMPUTER PROBLEM-SOLVING	93
24.	VOICE VERSUS WRITTEN COMMUNICATIONS FOR PROBLEM SOLVING	96
25.	PRESENTING NUMERIC DATA IN PERSON-COMPUTER DIALOGUE	99
26.	PRESENTING TEXT DATA IN PERSON-COMPUTER DIALOGUE	101
27.	PRESENTING TABULAR DATA IN PERSON-COMPUTER DIALOGUE	103
28.	GRAPHICS IN PERSON-COMPUTER DIALOGUE	105
29.	INFORMATION CODING IN PERSON-COMPUTER DIALOGUE	107
30.	ABBREVIATIONS AND ACRONYMS	110
31.	PROMPTING IN PERSON-COMPUTER DIALOGUE	113
32.	SCREEN LAYOUT AND STRUCTURING OF PERSON-COMPUTER DIALOGUE DISPLAYS	115
33.	GUIDELINES FOR MULTIPLE-FRAME DISPLAY DESIGN	119
34.	DESIGN GUIDELINES FOR MULTIPLE-LEVEL DISPLAYS	121
35.	WINDOWING VERSUS SCROLLING ON VISUAL DISPLAY TERMINALS	123
36.	GUIDELINES FOR USE OF NONCRITICAL AUDITORY SIGNALS	126
	BIBLIOGRAPHY	128

LIST OF TABLES

Table		Page
1.	BASIC DIALOGUE PROPERTIES AND CONSIDERATIONS	17
2.	COMPARISON OF INTERACTIVE DIALOGUES	21
3.	TRAINING AND RESPONSE TIME REQUIREMENTS FOR SELECTED DIALOGUE TYPES	24
4.	INTERFACE COMPONENT OF DATA BASE SYSTEMS	26
5.	OVERVIEW OF INTERACTIVE SYSTEM MODELING TECHNIQUES	29
6.	DESCRIPTIONS OF THE OPERATORS IN THE KEYSTROKE MODEL	32
7.	RULES FOR PLACING THE M OPERATIONS	33
8.	SAMPLE PROTOCOL ANALYSIS	37
9.	ELEMENTS OF THE PREDICTION PROCESS	42
10.	CLASSIFICATION OF ERRORS	49
11.	REDUCTION OF SELECTED ERROR TYPES	50
12.	TAXONOMY OF INTERACTIVE SYSTEMS USERS: SELECTED DIMENSIONS	53
13.	SELECTED GUIDELINES FOR DESIGNING PERSON-COMPUTER DIALOGUE FOR THE CASUAL USER	55
14.	RECOMMENDED SYSTEM RESPONSE TIMES	58
15.	USER PROBLEMS WITH QUERY LANGUAGES	66
16.	GUIDELINES FOR QUERY LANGUAGE DESIGN	67
17.	COMPARISON OF THREE QUERY LANGUAGES: TIME, ACCURACY, AND SUBJECT CONFIDENCE	69
18.	GUIDELINES FOR DESIGN OF DATA ENTRY DISPLAYS	74
19.	MEAN INPUT TIME DIFFERENCES BETWEEN LEVELS OF THE MAIN EFFECTS	77
20.	FREQUENCY OF POINT-IN AND TYPE-IN ERRORS LISTED BY ERROR TYPE	77

LIST OF TABLES (Cont.)

Table		Page
21.	MEAN ERROR SCORE DIFFERENCES BETWEEN LEVELS OF THE MAIN EFFECTS	78
22.	SELECTED GUIDELINES FOR DESIGN OF SEQUENCE CONTROL	81
23.	GUIDELINES FOR ERROR DETECTION, MESSAGE DESIGN AND CORRECTION	85
24.	SELECTED DESIGN CONSIDERATIONS FOR POSITION DESIGNATION CURSORS	87
25.	SELECTED GUIDELINES FOR DESIGN OF ON-LINE AND OFF-LINE DOCUMENTATION	89
26.	DIFFERENCES BETWEEN THE ON-LINE HELP MODIFIED FOR NON-PROGRAMMERS AND THE SYSTEM FOR PROGRAMMERS	90
27.	RELATIONSHIP OF AIDING MECHANISMS TO TYPES OF PROBLEM-SOLVING BEHAVIOR	94
28.	PROBLEM-SOLVING TIME FOR SEVEN MEASURES OF COMMUNICATIONS	97
29.	GUIDELINES FOR DISPLAY OF NUMERIC DATA	100
30.	CONSIDERATIONS FOR DISPLAY OF TEXT DATA	101
31.	GUIDELINES FOR DISPLAY OF TABULAR DATA	103
32.	DESIGN GUIDELINES FOR GRAPHIC PRESENTATIONS	106
33.	GENERAL GUIDELINES FOR SELECTION OF INFORMATION CODING TECHNIQUES	108
34.	GUIDELINES FOR DESIGN OF ABBREVIATIONS AND ACRONYMS	111
35.	INPUT FORMAT AND RECOMMENDED PROMPT FORMS	113
36.	GUIDELINES FOR SCREEN LAYOUT AND STRUCTURING	115
37.	LISTING OF GUIDELINES FOR MULTIPLE-LEVEL DISPLAYS	120
38.	MULTIPLE-LEVEL DISPLAY CONSIDERATIONS	121
39.	MAJOR FINDINGS OF WINDOWING VERSUS SCROLLING RESEARCH	124
40.	GUIDELINES FOR DESIGN OF AUDITORY SIGNALS	126

LIST OF FIGURES

Figure		Page
1.	Possible steps in dialogue design	14
2.	Observed execution times versus predicted times by the Keystroke Model	33
3.	Elements of user action language	41
4.	Schematic diagram of playback system	44
5.	Experimenter station and sample of objective observations	45
6.	Example of playback screen	46
7.	Dialogue power and ease-of-use	63
8.	Confidence rating to correctness ratio	70
9.	Problem-solving time for five communications types	98
10.	Data network overview showing windowing page boundaries and an example scrolling page	123

INTRODUCTION

PROGRAM BACKGROUND

This report is a collection of Compendium Entries on the topic of person-computer dialogue, written according to a format promulgated by the USAF Aerospace Medical Research Laboratory for a program called Integrated Perceptual Information for Designers (IPID). The IPID program was sponsored by a multi-agency effort, under the direction of Dr. Kenneth R. Boff at AMRL. It was intended to integrate the knowledge (data) from experimental psychology and human factors engineering into a Compendium of brief entries comprising principles, models, or experimental results (Boff, 1982). With extensive cross referencing, this compendium would enable design engineers to access human factors information in a convenient, condensed form, each entry being a maximum of two pages in length. Ultimately, the compendium is intended to be available in a computer data base that will be accessible to the engineer by a "friendly" interface to assist in selecting appropriate compendium entries for the specific engineering task.

The human factors engineering portion of the compendium (as opposed to the experimental psychology portion) was called the Human Engineering Data Base (HEDB). Essex Corporation was responsible for generating HEDB compendium entries in seven topical areas:

- Information coding, portrayal and format
- Target detection, recognition and identification
- Automation and person-computer function allocation
- Person-computer dialogue
- Feedback, warning and attentional directors
- Controls
- Human performance reliability

TOPIC BACKGROUND

Person-computer dialogue refers to the two-way exchange of information between a user and a computer. The term dialogue is borrowed from interpersonal communication, but at present, person-computer dialogues are considerably more limited than interpersonal dialogue. The characteristics of person-computer dialogue, obviously, are attributable to the characteristics of both the user and the hardware/software system. The attempt to provide system designers with guidelines for achieving good person-computer dialogues assumes an underlying dimension of "goodness" or quality of the dialogue. Although "good" dialogue is both rare and perhaps impossible to achieve, the criteria are likely to be:

- Productivity
- Efficiency
- Ease of use
- Error reduction
- User satisfaction

Humans have a great capacity to change. They adapt, adjust, accommodate, acclimatize, and learn. Therefore, they are likely to master nearly any system interface, given the time and motivation. Unfortunately, some system designers rely heavily on the plasticity of human behavior and deemphasize the careful design of the system's dialogue properties.

METHODOLOGY

The Compendium Entries in this report were created according to a process that involved the following steps: topic elaboration, bibliography development, literature acquisition and review, development of candidate entry listings (CELs), review and selection of CELs by an independent panel, and expansion and integration of the CELs to Compendium Entries.

Each Compendium Entry was intended to be a stand-alone mini-document on a specific topic area. Hence, the final report has a loose organization rather than one of impeccable continuity. Furthermore, the topics selected and data which have been reported are limited by their availability at the time of writing. Since then, literally reams of additional information have been generated. Unfortunately, it could not be integrated into the present report.

STATUS OF GUIDELINES FOR PERSON-COMPUTER DIALOGUE

While generating the CELs, the authors noted a serious lack of empirical support for most of the guidelines that have been recommended for person-computer dialogue. This lack of data led the government program managers to recommend publishing the Compendium Entries for the person-computer dialogue area as a separate document; hence, this report.

There seem to be two schools of thought regarding the advancement of person-computer dialogue. One emphasizes the immediate need for guidelines to support hardware and software developers, and the other emphasizes the need for solid empirical support before establishing guidelines. At the present time, several sources of guidelines are available, although they differ in their currency, level of analysis, and system-specificity (Engel and Granda, 1975; Ramsey and Atwood, 1975; Smith and Aucella, 1983; Williges and Williges, 1984). Several of these studies did not attempt to generate new guidelines, but to review and consolidate previous ones. The present study followed a similar process. The problem with this method is that the caveats and constraints that may have originally accompanied the guidelines tend to disappear with review and consolidation. Consequently, a set of guidelines achieves a life of its own, safely immune to critiques of the procedures followed in their development, the limits of their applicability or, in some cases, a lack of empirical foundation.

The literature pertaining to person-computer dialogue (see Bibliography) is replete with good ideas, specific examples and stimulating discussion -- but not data. Solid empirical data that can be generalized and forged into design guidelines are very rare. The Keystroke Model of Card, Moran, and Newell (1983) is one of the few examples that can be given of a model that was derived from data and validated against several systems.

Why are ideas so abundant but data so sparse in the area of person-computer dialogue? Three possibilities are suggested: (1) the study of PCD is a relatively new area of endeavor, arising only recently in the wake of the microcomputer "revolution;" (2) experimental procedures and methodology are difficult in studying dialogue because of the large number of variables that can apply, on both sides of the interface. Consequently, the results of many studies of person-system interaction are difficult to generalize; (3) the system development process rarely makes provision for empiricism. A negligible amount of the total resources devoted to computer system development is allocated to research on fundamental issues in human-computer interaction.

There is a need for a systems approach to fundamental research on human-computer interaction. Too often the research is driven by "quick and dirty" studies designed to answer a design question relative to a specific system. In addition to this basic research, other needs can be identified from reviewing the literature in the area. For example, who are the design guidelines intended for -- design engineers or human factors specialists? Ideally, an interdisciplinary design team would be assigned to a system development task. Team membership may include expertise in hardware, software, human factors, artificial intelligence, training, linguistics and cognitive psychology. This interdisciplinary expertise could greatly enhance the dialogue properties of the system. A related issue is how the characteristics of dialogue should be described in a language that is useful across the disciplines. Flowcharts, pseudo-code and formal grammars are candidates for providing a common medium for communicating the functional design of a dialogue system. And finally, what techniques are advisable for testing alternative dialogue designs? It is likely that simulation, modeling and field testing would contribute to the refinement of the dialogue design. Further development of such techniques seems warranted, particularly with respect to user differences and variabilities.

Development and validation of guidelines, however, cannot be the solitary goal of the future. A unified recognition of the human factors concerns and interdisciplinary complexity of person-computer dialogue must be actively fostered between designers and those in the related disciplines.

In surveys of system planners, designers, programmers and developers, there was limited mention of four basic features of human factors in design: (1) Understand the user, (2) involve the user in the design team, (3) test the system with typical users early in the design and (4) fix problems identified in early testing through iterative design (Gould & Lewis, 1983). These results indicate that the majority of designers may not be thoroughly educated in (or convinced of the utility of) these issues.

Gould and Lewis (1983) indicate that even when these tenets of human factors are acknowledged, the understanding of them by designers may differ significantly from the original intent. What is common sense to one person cannot possibly be common sense to another if both parties do not share a mutual awareness of the vital issues. It appears critical that the future of research in person-computer dialogue include education of the designers in the utility of the data, as well as the applications. Furthermore, a concerted effort must be made to reduce the parochialism which exists between designers and researchers of the various disciplines. Once this is accomplished, greater progress will be made in the field of person-computer dialogue.

FUTURE DIALOGUE DESIGN

Future dialogue between people and computers may expand considerably over the limited dialogue that is now possible. Verbal dialogue, with limited vocabularies and other constraints is possible now (McCauley, 1984), and the long-promised breakthroughs in artificial intellience (AI) portend increased capability for the computer to adapt to the characteristics of the user, rather than vice versa.

REPORT OBJECTIVES

This report may serve to identify issues and gaps in our knowledge of person-computer dialogue. It may provide some useful guidelines for system designers, although many caveats must be kept in mind. The bibliography may serve as a resource for those interested in pursuing the literature. Most of all, we hope that the report will stimulate research and empirical validation of guidelines for person-computer dialogue.

This report does not cover several important areas of human-computer interaction, such as controls and displays (covered in other topic areas of the HEDB program) and human factors in software development (Shneiderman, 1979).

It was well beyond the resources of the present project to attempt to validate the guidelines reported herein. Thus, we risk the potential for fostering and transmitting guidelines that may be ill-founded, only partially correct, or applicable only for certain types of users or systems. The design engineer who reads this document is advised to proceed with caution and thoughtful skepticism.

1. STEPS IN PERSON-COMPUTER DIALOGUE DESIGN

KEY TERMS

DESIGN STEPS; DIALOGUE DESIGN STRUCTURE; DESIGN PHASES

GENERAL DESCRIPTION

Figure 1 displays a systematic sequence of analyses for the design of a person-computer dialogue. In such a system, the user typically provides the greatest variability of any system component. The design of a successful dialogue-based system relies heavily on thorough systematic analyses from which the needs, characteristics, and capabilities of all system components, including the human, can be understood and integrated into a successful design.

Analyses to determine the types and characteristics of all potential users must be carefully conducted. An erroneous assumption is easily made that the designer already knows who the user is; imperfect design requirements result. Steps 2 through 5 specifically address the types of system users, their role in the system, and the user's capabilities.

With full knowledge of the user in mind, system hardware/software requirements can be established. Steps 7 through 11, including their requisite feedback loops, provide the opportunity to match the hardware and software with the needs and capabilities of the user groups. These steps should include the human factors considerations of the hardware (i.e., operator comfort, workspace layout and illumination/CRT glare), as well as system response time and operator workload.

Steps 12 through 16 involve the design of the initial dialogue structure and support software, error and failure control procedures. Step 17 represents a critical design step, dialogue simulation experiments prior to actual coding of the dialogue software (Steps 18 to 20). Participation of the future system users, at all levels, in this aspect of the design process provides valuable feedback to the designers regarding the acceptability of the dialogue to the users. Furthermore, user involvement at this phase can "build in" a sense of commitment to the new system, easing potential negative acceptance when the system becomes operational.

"Bullet-proofing", the final step (Number 21), is an attempt to design "safety" features to protect the system from tampering. Tampering may be due to experimentation, boredom, confusion, or misunderstanding of the system or dialogue. It may even be malicious and deliberate. This tampering can, in some cases, be predicted, given a complete understanding of the user groups. Other potential problems, as well as solutions to them, can be identified in simulation/system trials with representative users. It is critical that these trials be performed with representative users, not system engineers, programmers, etc. No matter how open-minded the system designers are, only a representative user can react like a real system user.

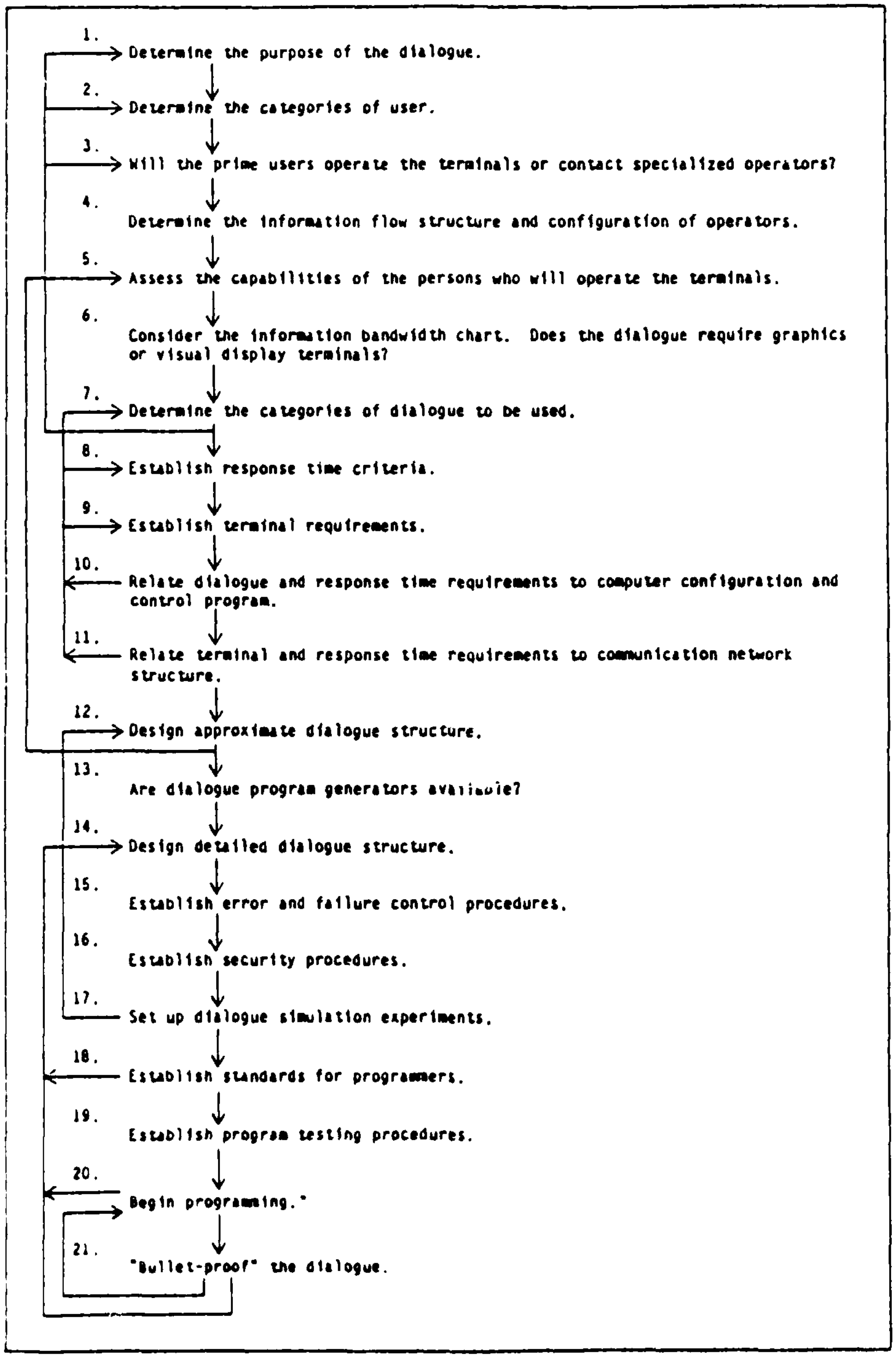


Figure 1. Possible steps in dialogue design. (Source: Martin, 1973)

APPLICATIONS

This approach will aid the development of new systems that may/will include person-computer dialogue; troubleshooting of existing dialogue which is not achieving performance or acceptance standards.

CONSTRAINTS

- Applicability of specific steps may vary with system type or needs.

KEY REFERENCES

1. Hendricks, D., Kilduff, P., Brooks, P., Marshak, R., & Doyle, B. (1982). Human engineering guidelines for management information systems. Alexandria, VA: U.S. Army Materiel Development and Readiness Command.

2. Martin, J. (1973). Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.

CROSS REFERENCES

2. Basic properties of person-computer dialogue; 3. Comparison of approaches to person-computer dialogue

2. BASIC PROPERTIES OF PERSON-COMPUTER DIALOGUE

KEY TERMS

INTERACTIVE DIALOGUE; INITIATIVE; FLEXIBILITY; COMPLEXITY; INFORMATION LOAD

GENERAL DESCRIPTION

All person-computer dialogues involve five basic properties described in Table 1.

(A) The dialogue is "computer-initiated" if the computer asks questions, presents alternatives, etc., and the user responds. If the user inputs commands without such computer "prompting," the dialogue is "user-initiated." Combinations of computer and user initiated dialogues, either "mixed" or "variable," are also possible.

(B) Flexibility is a measure of the number of ways in which a user can accomplish a given function. High flexibility can be achieved by providing a large number of commands, by allowing the user to define or redefine commands, etc.

(C) Complexity, related to flexibility, is a measure of the number of options available to the user at a given point in the dialogue. Low complexity can be achieved by using few commands, or by partitioning the commands so that the user selects from a small set at any given time.

(D) Power, related to flexibility and complexity, is the amount of work accomplished by the system in response to a single user command. In a dialogue with powerful commands, the user may accomplish, with a single command, an operation which would require several commands in a system with less powerful commands.

(E) Information load is a measure of the degree to which the interaction absorbs the memory and/or processing resources of the user.

APPLICATIONS

Selection of a dialogue type requires consideration of the five basic properties, listed above, which dialogue types have in common in order to select appropriate dialogue types.

CONSTRAINTS

- "Mixed initiative" or variable (user selectable) initiative may be useful in situations involving varied user types.
- Selection of initiative mode must consider dialogue structure and transaction content in addition to user types and system response time.
- Flexibility is difficult to measure in existing dialogue design.

TABLE 1. BASIC DIALOGUE PROPERTIES AND CONSIDERATIONS
(Source: Ramsey & Atwood, 1979)

PROPERTY	DESIGN CONSIDERATIONS	REFERENCES
A. Initiative	COMPUTER INITIATED: o For naive or casual users o Relies on passive rather than active vocabulary o Can teach a "system model" to unfamiliar users o Satisfactory for experienced users if system response is fast o Can constrain the amount of information in a transaction USER INITIATED: o For experienced users o For frequently used actions or rapid interchanges	Ref. 6 Ref. 7 Ref. 12 Ref. 13
B. Flexibility	HIGH FLEXIBILITY: o For experienced/sophisticated users o Increases error rate of inexperienced users o Results in use of known problem-solving solutions rather than known, but unlearned, less cumbersome alternatives	Ref. 4 Ref. 11 Ref. 15 Ref. 16
C. Complexity	o Optimal level is a function of task and user type o Deviation from optimal complexity results in degraded performance o Redundant or irrelevant commands impair performance	Ref. 1 Ref. 2 Ref. 3
D. Power	o Must correspond to user's needs, which can change over time o System generality reduces with use of powerful rather than less powerful basic commands o Powerful commands, in conjunction with basic commands, increase complexity	Ref. 4 Ref. 11 Ref. 17
E. Information Load	o Performance degrades if load is too high or too low o Load can be empirically measured or estimated o Load is a major success factor, but not often a formal design consideration	Ref. 5 Ref. 8 Ref. 10 Ref. 14

- Complexity, as defined here, describes cognitive complexity at dialogue decision modes, not structural complexity.
- No clear guidance on optimal complexity exists in the literature.
- No standard metric of dialogue power exists.
- Measurement of workload and information load may be a problem.

KEY REFERENCES

1. Baker, J. D., & Goldstein, I. (1966). Batch vs. sequential displays: Effects on human problem solving. Human Factors, 8, 225-235.
2. Boies, S. J. (1977). Behavioral issues in the use of interactive systems. Unpublished study cited in Miller and Thomas, p. 512 (1977). International Journal of Man-Machine Studies, 9, 509-536.
3. Carlisle, J. H. (1974). Man-computer interactive problem solving: Relationships between user characteristics and interface complexity. Doctoral dissertation, Yale University (University Microfilms No. 74-25725). (NTIS No. AD 786466)
4. Eason, K. D. (1976, September). A task-tool analysis of manager-computer interaction. Paper presented at NATO Advanced Study Institute on Man-Computer Interaction, Mati, Greece. (Reprinted by Department of Human Sciences, University of Technology, Loughborough, Leicestershire, England.)
5. Finkelman, J. M. (1976). Information processing loads as a human factors criterion for computer systems design. In R. E. Granda & J. M. Finkelman (Eds.), The role of human factors in computers. Proceedings of a symposium co-sponsored by the Metropolitan Chapter of the Human Factors Society and Baruch College, City University of New York. New York, NY: Human Factors Socety, Metropolitan Chapter, 1-6.
6. Johnson, J. K. (1977). Touching data. Datamation, 23(1), 70-72.
7. Martin, J. (1973) Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.
8. Meister, D. (1976). Behavioral foundations of system development. New York, NY: Wiley.
9. Parsons, M. M. (1972). Man-machine system experiments. Baltimore, MD: The Johns Hopkins Press.

*10. Ramsey, H. R., & Atwood, M. E. (1979). Human factors in computer systems: A review of the literature (SAI-79-111-DEN). Englewood, CO: Science Applications, Inc. (NTIS No. AD A075679)

11. Stewart, T. F. M. (1976). The specialist user. Paper presented at NATO Advanced Study Institute on Man-Computer Interaction, Mati, Greece. (Reprinted by Department of Human Sciences, University of Technology, Loughborough, Leicestershire, England.)
12. Thompson, D. A. (1969). Man-computer system: Toward balanced co-operation in intellectual activities. In Proceedings, International Symposium on Man-Machine Systems (IEEE Conference Record No. 69C58-MMS, Vol. 1). New York, NY: Institute of Electrical and Electronics Engineers.

*Principal reference

13. Thompson, D. A. (1971). Interface design for an interactive information retrieval system: A literature survey and a research system description. Journal of the American Society for Information Science, 22, 361-373.
14. Treu, S. (1975). Interactive command language design based on required mental work. International Journal of Man-Machine Studies, 7, 135-149.
15. Walther, G. H. (1973). The on-line user-computer interface: The effects of interface flexibility, experience and terminal-type on user-satisfaction and performance. Colorado Springs, CO: U. S. Air Force Academy, Department of Astronautics and Computer Science. (Also doctoral dissertation, University of Texas, Austin, Texas.) (NTIS No. AD 777314)
16. Walther, G. H., & O'Neil, H. F., Jr. (1974). On-line user-computer interface: The effects of interface flexibility, terminal type, and experience on performance. AFIPS Conference Proceedings, 43, 379-384.
17. Wood, R. C. (1972). Inferences from the UCSB on-line system for man-system interface design. In Proceedings of the 1972 International Conference on Cybernetics and Society (pp. 120-125). New York, NY: Institute of Electrical and Electronics Engineers, Inc.

CROSS REFERENCES

1. Steps in person-computer dialogue design

3. COMPARISON OF APPROACHES TO PERSON-COMPUTER DIALOGUE

KEY TERMS

DIALOGUE LANGUAGES; INPUT-OUTPUT; DIALOGUE CATEGORIES

GENERAL DESCRIPTION

Before selecting a particular dialogue type for a particular application, the characteristics and abilities of the user must be accurately defined. Table 2 provides a comparison of eighteen approaches to interactive dialogue. For each dialogue type, advantages and disadvantages are noted, considering issues including limitations/advantages, user-type effects, cost considerations, and limitations of application. Table 3 lists training and system response time requirements for the major dialogue types.

APPLICATIONS

Selection of interactive dialogue type.

CONSTRAINTS

Selection of dialogue should include consideration of:

- User characteristics and abilities;
- Hardware characteristics and limitations;
- Information bandwidth requirements;
- Current state-of-the-art technology.

KEY REFERENCES

*1. Martin, J. (1973). Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.

2. Smith, S., & Aucella, A. (1983). Design guidelines for the user interface to computer-based information systems. Bedford, MA: The MITRE Corporation.

CROSS REFERENCES

1. Steps in person-computer dialogue design; 13. System response time and the effect on user performance and satisfaction; 14. Information bandwidth in person-computer dialogue

*Principal reference

TABLE 2. COMPARISONS OF INTERACTIVE DIALOGUES (Source: Martin, 1973)

TYPE OF DIALOGUE	ADVANTAGES	DISADVANTAGES
Programming languages	Concise, precise, powerful, flexible.	Inappropriate for the vast number of terminal users who have not learned to program and do not want to (e.g., management, general public, administrative staff).
English-language dialogue	Theoretically, the most natural man-machine interface.	Unsuitable where an operator's input must be interpreted with precision because of the ambiguity of our language. Immense software problems. On commercial applications, it constitutes a trap to be avoided. Sometimes satisfactory for computer-assisted instruction.
Limit English input	Users employ words they are familiar with.	Some users tend to overestimate the intelligence of the machine and overstep the tight restrictions on input wording.
Question and answer dialogues (in which the computer asks the operator a series of questions)	Very simple for the operator. Can be written with a simple program.	Of limited flexibility. Suitable for certain applications only.
Dialogue using mnemonics	Can be concise and precise (e.g., airline reservation dialogue).	Operator must be familiar with mnemonics and formats.
Dialogue with programming-like statements	Can be concise and precise.	Operator must be well trained, familiar with the coding, and have a limited programming aptitude.
Computer-initiated dialogues (in which the operator responds to the computer rather than the computer responding to the operator)	The computer tells the operator what to do; little training required. Can be used with a totally untrained operator.	Dialogue can be lengthy and often slow. Many characters; high line utilization; more expensive networks. Little flexibility in sequence of operation.

TABLE 2. COMPARISONS OF INTERACTIVE DIALOGUES (Source: Martin, 1973) (Cont.)

TYPE OF DIALOGUE	ADVANTAGES	DISADVANTAGES
Form-filling (in which the operator fills out a "form" on a visual display)	Straightforward for operator except for cursor manipulations.	Less flexible than a "branching tree" of questions, and error correction procedures are less easy.
Menu-selection dialogues	Simple for the operator. Can be written with a simple program generator.	Limited in scope. Large number of characters used; more expensive telecommunication network.
Build dialogue features into special terminal hardware	The intent is usually to clarify and simplify the operator actions. A similar effect could often be achieved without special hardware, however.	Expensive. Inflexible. May restrict future development.
Dialogues with a light pen for input (or other means of pointing to the screen)	Simple form of input, ideal for an untrained operator. Can make a complex dialogue fast.	Limited in scope unless a keyboard is used as well as the light pen.
Fixed-panel responses (in which the computer responds with one of a standard set of panels)	Simple for programming. The panels can be stored in devices away from the main computer, giving low transmission requirements. In some cases, panels with pictures may be used.	Inflexible. Of limited scope.
Modifiable-panel dialogues (in which the panels can be modified by the programs)	Can also save transmission requirements. Simpler than tree-form dialogues.	Loses the simplicity of fixed-panel dialogues.
Graphics using chart displays	Very effective for summarizing information and manipulating models. Ideal for many dialogues with management.	Expensive. Elaborate programming requirements (which may be available through software). On teleprocessing systems "intelligent" terminals are needed to avoid bandwidth restraints.

TABLE 2. COMPARISONS OF INTERACTIVE DIALOGUES (Source: Martin, 1973) (Cont.)

TYPE OF DIALOGUE	ADVANTAGES	DISADVANTAGES
Graphics using symbol manipulation	Very effective for complex problem solving, engineering design, etc.	Expensive. Elaborate programming requirements. "Intelligent" terminals.
Dialogues with photographic frames	Photographs are valuable in certain applications (e.g., real estate, personnel, engineering, parts, systems used by children). They may become extensively used when home CATV terminals come into use.	Telecommunication channels in use, other than CATV, have insufficient bandwidth for photograph transmission. The images must therefore be stored at the terminal location.
Voice answerback dialogues	The telephone is the cheapest available terminal.	Limited in what can be accomplished.
Dialogue via a third party	Many important uses (e.g., information room, data secretaries, telephone agents, counter clerks). Enables management and the general public to obtain information from computers.	Generally prevents extended use of the terminal.

TABLE 3. TRAINING AND RESPONSE TIME REQUIREMENTS FOR SELECTED DIALOGUE TYPES (Source: Smith & Aucella, 1983)

DIALOGUE TYPE	REQUIRED USER TRAINING	REQUIRED SYSTEM RESPONSE TIME
Question and Answer	Little/None	Moderate
Form Filling	Moderate/Little	Slow
Menu Selection	Little/None	Very Fast
Function Keys with Command Language	High/Moderate	Fast
User-Initiated Command Language	High	Fast
Query Languages	High/Moderate	Moderate
Natural-Language Dialogues	Moderate (potentially little)	Fast
Interactive Graphics	High	Very Fast

4. MAJOR DATA MODELS IN DATA BASE SYSTEMS

KEY TERMS

DATA BASE; TAXONOMY; CENTRALIZATION; USER TYPES; DATA TYPES; DATA MODELS: EXPLICIT AND IMPLICIT; RELATIONAL MODELS; HIERARCHICAL MODELS; NETWORK MODELS; QUERY LANGUAGE; COMPUTER SYSTEM MODELS; MODELS OF HUMAN INFORMATION PROCESSING

GENERAL DESCRIPTION

Data base systems are composed of three separate, yet interactive components: users, centralized data, and centralized interface. Centralization is the key concept which reduces data duplication and facilitates enforcement of data integrity and security controls. Centralization creates an independence of data. The diversity of potential users makes it vital to tailor the interface to the appropriate user group.

The centralized interface is the system component in which human factors optimization includes selection of a query language which is appropriate to the type of user and data model. As shown in Table 4, Implicit Data Models must also include human factors considerations including optimization of natural-language dialogues, screen layouts and number of menu items. Query languages for the implicit data model facilitate use by novice or nontechnical users. Explicit Data Models are more suitable for use by professional programmers. The relational model (Ref. 3) utilizes a tabular structure in which the columns contain values from a single domain. Hierarchical models organize data elements into a tree structure. Network models (Ref. 1) group data elements into records, which are organized into data-structure sets via use of pointers.

APPLICATIONS

Data base systems; data base design; subschema design.

CONSTRAINTS

Selection of a data model requires consideration of:

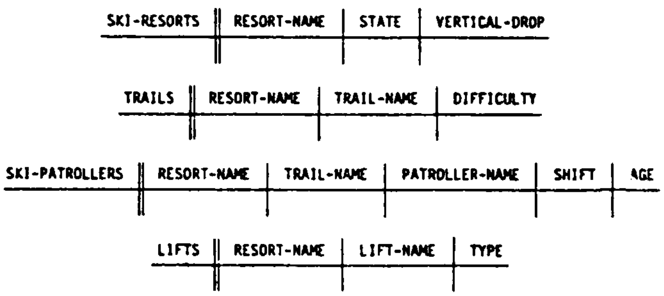
- Type of user
- Logical organization of data
- Perception of data organization by potential users (Ref. 5)
- Human factors criteria, including simplicity, elegance, picturability, modeling directness, overlap with co-resident models, partitionability of data, and nonconflicting terminology (Ref. 7)
- Selection of variable names to ensure comprehension by users.

User confusion can result from:

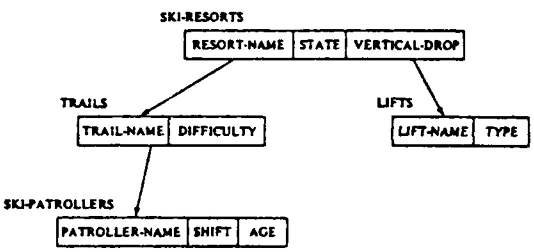
- Restricted and formal meaning of common English words
- Misinterpretations of application-domain limitations when unrestricted natural language is used
- High number of relations in relational data models; fewer relations with more columns can reduce query complexity

TABLE 4. INTERFACE COMPONENT OF DATA BASE SYSTEMS

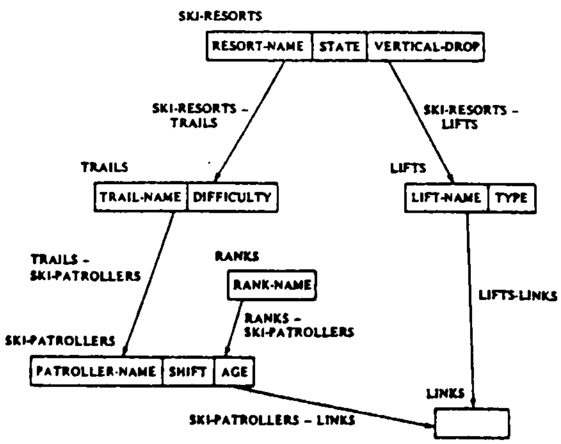
<table>
<tr><th>DATA MODEL</th><th>CHARACTERISTICS</th><th>QUERY LANGUAGE TYPE</th></tr>
<tr><td>A. Implicit Data Models</td><td>Does not provide logical view of data to user.
Involves knowledge of application area rather than data components.</td><td>Natural Language
• Simple English
• Psuedo English
• English-like
Computer Initiated
• Menu selection
• Question & answer
• Parameter specification</td></tr>
<tr><td>B. Explicit Data Models (from Shneiderman, 1980)
• Relational



Example schema diagram for relational database.</td><td>Avoids implementation details.
Promotes data independence.
Separates logical and physical data issues.</td><td>Non-procedural languages</td></tr>
<tr><td>• Hierarchical



Example schema diagram for hierarchical information database.</td><td>Easy to understand.
Limits complexity of data relationships.
Allows "one to many" relationships</td><td>Procedural, formal languages</td></tr>
<tr><td>• Network



Example schema diagram for network-model database with LINKS and RANKS information.</td><td>Includes additional features for:
- Organizing information
- Searching efficiently
- Storing records
- Controlling privacy
- Checking integrity
- Facilitating data administration
Allows "many to many" relationships.</td><td>Host-embedded data manipulation languages, including:
- PL/1
- Cobol
- Fortran
- Assembler</td></tr>
</table>

- o Inadequate "depth versus breadth" trade-offs in hierarchical data models
- o Use of records with multiple owner record types and cyclic schema in network data models.

KEY REFERENCES

1. Brosey, M. K., & Shneiderman, B. (1978). Two experimental comparisons of relational and hierarchical data base models. International Journal of Man-Machine Studies, 10, 625-637.
2. CODASYL DBTG. (1971). CODASYL data base task group report, Conference Data Systems Languages. New York, NY: Association for Computing Machinery.
3. Codd, E. F. (1970). A relational model of data for large shared data banks. Communications of the ACM, 13(6), 377-387.
4. Date, C. J. (1977). An introduction to database systems (2nd Ed.). Reading, MA: Addison-Wesley.
5. Durding, B. M., Becker, C. A., & Gould, J. D. (1977). Data organization. Human Factors, 19(1), 1-14.
*6. Greenblatt, D., & Waxman, J. (1978). User oriented query language design. In Proceedings of the Human Factors and Computer Science Symposium (pp. 78-102). Santa Monica, CA: Human Factors Society.
7. McGee, W. C. (1976). On user criteria for data model evaluation. ACM Transactions on Database Systems, 1(4), 370-387.
8. Ramsey, H. R., & Atwood, M. E. (1979). Human factors in computer systems: A review of the literature (SAI-79-111-DEN). Englewood, CO: Science Applications, Inc. (NTIS AD A075 679)
*9. Shneiderman, B. (1980). Software psychology: Human factors in computer and information systems. Cambridge, MA: Winthrop Publishers.

CROSS REFERENCES

1. Steps in person-computer dialogue; 2. Basic properties of person computer dialogue

---

*Principal reference

5. TECHNIQUES FOR MODELING INTERACTIVE SYSTEMS

KEY TERMS

SYSTEM MODELING; SIMULATION

GENERAL DESCRIPTION

Five approaches to modeling interactive systems are discussed in Table 5. Section (A) describes network models intended to define the relationships between system and user tasks in terms of expected performance and logical predecessor-successor relationships; (B) models based on control-theory, statistical estimation, and decision theory which regard users as feedback loop elements; (C) decision-theory models which allow selection of courses of action based on users' decision-making behaviors; (D) models of human information processing which analyze the problems to be solved and protocols used by problem-solvers during solution; and (E) computer system models which describe only the computer component behavior of interactive systems but do not model, in detail, the behavior of users.

APPLICATIONS

Examination of the effects of alternative design decisions prior to selection of appropriate dialogue design; evaluation of user and task properties.

Network Models
- Linear tasks - single or multiple path

Control-Theory Models
- Control-type tasks
- Tasks with use of well-learned algorithms/procedures

Decision-Theory Models
- Tasks with selection of alternatives and evaluating outcomes

Models of Human Information Processing
- Tasks with human as information processor
- Models exist for well-specified tasks where complete model is not necessary

Computer System Models
- Descriptions of computer behavior
- Determining if user requirements are satisfied
- Optimizing overall performance in existing systems

TABLE 5. OVERVIEW OF INTERACTIVE SYSTEM MODELING TECHNIQUES
(Source: Ramsey & Atwood, 1979)

APPROACH	CHARACTERISTICS	REFERENCES
A. Network Models	Usually used to predict either the probability of failure or "success," or the completion time, of an aggregate set of tasks. Allow performance data about user and computer system to be integrated in a single model even though original data came from a variety of sources.	Ref. 1 Ref. 6 Ref. 9
B. Control-Theory Models	Usually used to predict overall performance of the user-computer system in continuous control and monitoring tasks. More quantitative than other performance models, but ordinarily do not deal with details of the interface, such as display design.	Ref. 6
C. Decision-Theory Models	Can be used to suggest "optimal" decisions or to describe the observed decision-making behavior of users. Frequently used in decision aids.	Ref. 6
D. Models of Human Information Processing	Ideally lead to an integrative model of human information processing useable in a variety of design applications. Existing models may be applicable to very specific tasks, if recognized as relevant.	Ref. 5 Ref. 6 Ref. 10
E. Computer System Models	Can be useful in determining whether or not user requirements with respect to response time and other gross system performance measures can be satisfied by a proposed system. Usually attempt to predict such performance factors as system response time, CPU and memory loads, and I/O requirements.	Ref. 2 Ref. 3 Ref. 4 Ref. 8

CONSTRAINTS

Development of interactive system models, in general, is limited by the following:

- Models based on memory and process limitations are restricted to simple tasks due to high detail demands.
- Validation of models used as dialogue design tools may not be practical.
- Successful models have been limited to simple task domains.
- Designer must thoroughly understand the task domain and information requirements.
- No general approach to model development exists.
- Other types of user-alone models exist, not yet adapted to interactive systems.

KEY REFERENCES

1. Baker, J. D., & Goldstein, I. (1966). Batch vs. sequential displays: Effects on human problem solving. Human Factors, 8, 225-235.
2. Carbonell, J. R. (1967). On man-computer interactions: A model and some related issues (BBN Report No. 1593). Cambridge, MA: Bolt, Beranek and Newman, Inc. (Also reported more briefly in IEEE Transactions on System Science and Cybernetics, 1969, SSC-5, 16-26.) (NTIS No. AD 666666)
3. Foley, J. D. (1971). An approach to the optimum design of computer graphics systems. Communications of the ACM, 14, 380-390.
4. Grignetti, M. C., Miller, D. C., Nickerson, R. S., & Pew, R. W. (1971). Information processing models and computer aids for human performance: Task 2: Human-computer interactions models (AFOSR-TR-71-2845). Cambridge, MA: Bolt, Beranek and Newman, Inc. (NTIS No. AD 732913)
5. Mann, W. C. (1975). Dialogue-based research in man-machine communication (ISI RR-75-41). Marina del Rey, CA: University of Southern California, Information Sciences Institute.
6. Pew, R. W., Baron, S., Feehrer, C. E., & Miller, D. C. (1977). Critical review and analysis of performance models applicable to man-machine systems evaluation (Report No. 3446). Cambridge, MA: Bolt, Beranek and Newman, Inc. (NTIS No. AD A038597)

*7. Ramsey, H. R., & Atwood, M. E. (1979). Human factors in computer systems: A review of the literature (SAI-79-111-DEN). Englewood, CO: Science Applications, Inc. (NTIS No. AD A075679)

8. Shemer, J. E., & Heying, D. W. (1969). Performance modeling and empirical measurements in a system designed for batch and time-sharing users. AFIPS Conference Proceedings, 35, 17-26.
9. Siegel, A. I., Wolf, J. J., & Leahy, W. R. (1973). A digital simulation model of message handling in the Tactical Operations System: I. The model, its sensitivity, and user's manual (Research Memorandum 73-5). Arlington, VA: U. S. Army Research Institute for the Behavioral and Social Sciences.

*Principal reference

10. Zeigler, B. P., & Sheridan, T. B. (1965). Human use of short-term memory in processing information on a console. IEEE Transactions on Human Factors in Electronics, HFE-6, 74-83.

CROSS REFERENCES

1. Steps in person-computer dialogue design; 6. Keystroke model for predicting task execution time; 7. A protocol analysis for documenting user problems with interactive systems; 8. Formal language as a design tool for person-computer dialogue; 9. Playback methodology for evaluating person-computer dialogue; 10. Interface design principles derived from human error analyses

6. KEYSTROKE MODEL FOR PREDICTING TASK EXECUTION TIME

KEY TERMS

RESPONSE TIME; TASK COMPLETION; KEYBOARD INPUT

GENERAL DESCRIPTION

The Keystroke Model estimates the time required for an expert user to accomplish a given task using an interactive computer system. Task execution time is described in terms of four physical-motor operators (K, P, H and D), one mental operator (M) and one system response operator (R). Table 6 describes the operators. Rules for placing the M-operations are defined in Table 7. An encoding method is given for specifying the series of operators in a task prior to applying the equation:

$$T_{execute} = T_K + T_P + T_H + T_D + T_M + T_R$$

The Keystroke Model has been validated against eleven systems, with the calculated and observed times for task execution shown in Figure 2.

TABLE 6. DESCRIPTIONS OF THE OPERATORS IN THE KEYSTROKE MODEL

OPERATOR	DESCRIPTION	TIME (sec)
K	Press key or button (includes shift or control keys). Time varies with skill:	
	Best typist (135 wmp)	.08
	Average typist (55 wmp)	.20
	Typing complex codes	.75
	Worst typist	1.20
P	Point with mouse to target on display (follows Fitt's Law, range .8 to 1.5 sec.)	1.10
H	Home - hands-on keyboard (or other device)	.40
D (n_d, l_d)	Draw n_d straight-line segments of total length l_d cm (assumes drawing straight lines with a mouse	$.9n_d + .16l_d$
M	Mentally prepare (see Table 7 for application rules)	1.35
R (t)	Response by the system (only if it causes the user to wait)	t

TABLE 7. RULES FOR PLACING THE M OPERATIONS
(Source: Card, et al., 1983)

All physical operations and response operations must be encoded. Use Rule 0 to place candidate M's, then cycle through Rules 1 to 4 for each M to see whether it should be deleted.
Rule 0. Insert M's in front of all K's that are not part of argument strings proper (e.g., text or numbers). Place M's in front of all P's that select commands (not arguments).
Rule 1. If an operator following an M is fully anticipated in an operator just previous to M, then delete the M (e.g., PMK → PK).
Rule 2. If a string of MKs belongs to a cognitive unit (e.g., the name of a command), then delete all M's but the first.
Rule 3. If a K is a redundant terminator (e.g., the terminator of a command immediately following the terminator of its argument), then delete the M in front of it.
Rule 4. If a K terminates a constant string (e.g., a command name), then delete the M in front of it; but if the K terminates a variable string (e.g., an argument string), then keep the M in front of it.

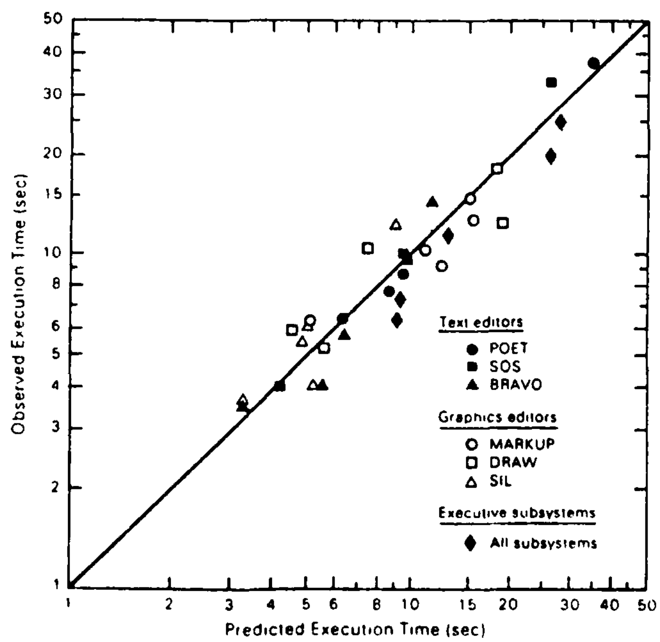


Figure 2. Observed execution times versus predicted times by the Keystroke Model.
(Source: Card, Moran and Newell, 1983)

APPLICATIONS

Has been used to predict execution times in (1) text-editing; (2) computer-graphics tasks and (3) system-executive tasks. Can be applied directly to tasks which are accomplished at a computer terminal using a keyboard and/or a mouse.

Method of Application

Given: A task (involving a sequence of subtasks; the command language of a system; the motor skill parameters of the user; the response time parameters of the system; and the method used for the task).

The Keystroke Model will predict: the time an expert user will take to execute the task (not including errors).

An example application is a text editing task of replacing a five-letter word with another five-letter word, one line below the previous modification:

System A		System B	
Jump to next line	MK[LINEFEED]	Reach for mouse	H[mouse]
Issue Substitute command	MK[S]	Point to word	P[word]
Type new 5-letter word	5K[word]	Select word	K[YELLOW]
Terminate new word	MK[RETURN]	Home on keyboard	H[keyboard]
Type old 5-letter word	5K[word]	Issue Replace command	MK[R]
Terminate old word	MK[RETURN]	Type new 5-letter word	5K[word]
Terminate command	K[RETURN]	Terminate type-in	MK[ESC]

Using the operator times from Figure 2, and assuming an average typing speed (t_K = .2 sec):

System A Execution Time: $T_{execute} = 2t_M + 8t_K + 2t_H + t_P = 6.2$ sec

System B Execution Time: $T_{execute} = 4t_M + 15t_K = 8.4$ sec

EMPIRICAL VALIDATION

The Keystroke Model was evaluated by comparing calculated and observed execution times in ten systems using 14 tasks, 28 operators and 1280 user-system-task interactions. The systems included three text editors, three graphics systems and four executive subsystems.

The data from the validation studies are shown in Figure 2, comparing the predicted and observed task execution times. The root-mean-square error was 21%.

CONSTRAINTS

- The model applies to the behavior of experienced users. Experienced users have lower variability. No metrics are available for low or moderately experienced operators.
- The model assumes error-free performance.
- Proper task analysis and encoding are prerequisites.
- Tasks that require acquisition time (to perceive, read or interpret displayed information) are not covered directly by the Keystroke Model.
- With highly repetitive tasks, users reduce their mental time below the model's predictions (M).
- The model does not apply to tasks that emphasize mental operations, such as composing text.

KEY REFERENCES

1. Card, S. K., Moran, T. P., & Newell, A. (1980). The keystroke level model for user performance time with interactive systems. Communications of the ACM, 23, 396-410.

*2. Card, S. K., Moran, T. P., & Newell, A. (1983). The psychology of human-computer interaction. Hillsdale, NJ: Lawrence Erlbaum.

CROSS REFERENCES

7. A protocol analysis for documenting user problems with interactive systems; 8. Formal language as a design tool for person-computer dialogue

*Principal reference

7. A PROTOCOL ANALYSIS FOR DOCUMENTING USER PROBLEMS WITH INTERACTIVE SYSTEMS

KEY TERMS

PERSON-COMPUTER DIALOGUE; SYSTEM DOCUMENTATION; USER PERFORMANCE; SYSTEM PERFORMANCE

GENERAL DESCRIPTION

Protocol analysis provides identification and documentation of cognitive mismatch between human and computer in interactive systems. This methodology involves a formalized interactive session during which terminal protocols (user performance) and verbal protocols (user-expressed cognitive activity) are observed and recorded. Both protocols provide complementary information: terminal protocol describes directly observable user behaviors and verbal protocols describe concurrent thought/reasoning processes or cognitive activities occurring during periods of no observable user behaviors. Collectively, the two protocols provide data from which hypotheses of user-computer mismatch can be formulated for empirical resolution.

The protocol analysis must fulfill two needs: (1) recording of protocols and (2) classification of protocols. During the session, the system user must be required to describe the aim and the expected system response before entering each command. Use of documentation or taking of notes by the system user is not allowed.

The experimenter must merge the two protocol streams into a single recording of the session, since the two are either concurrent or sequentially occurring. Distinctions, however, are maintained between problems in terminal protocol and verbal protocol. Problems deduced from terminal protocol are referred to as errors, those deduced from verbal protocol (or from both sources) are difficulties, and those from recollections of previous difficulties or errors are reminiscences. Each of these classifications are used to categorize interactive events. An example protocol session is provided in Table 8, including the keys for the protocol recording. To facilitate ease of collection and categorization, protocol observation data are coded in accordance with a standardized criterion.

APPLICATIONS

Documentation of person-computer interface mismatch; hypothesis generation for empirical research; validation of models.

Method of Application

Example of System Evaluation:

The most common cause of error was mistyping (33% of all errors). Further analysis showed that, with the majority of errors (51%), the

TABLE 8. SAMPLE PROTOCOL ANALYSIS (Source: Hammond, et al., 1980)

Example:

Person-Machine Interaction	Protocol Recording
Section 1.3.1 S: Now, I can't remember the format of average, # it's A V G E or something. I'll try it out anyway. Sounds logical. No, I don't think we should have an E, we'll just try A V G. And we'll say PEOPLE and it'll probably fail.	#Language: Lexical (D N+
#10:20;53: ?: *T<-<:AVE:AGE;>PEOPLE State: Waiting with OUTPUT flag	#Language: Syntax (E N+ M+ <Syntax appropriate for <operators rather than <functions
Section 1.3.2 S: What has happened, output, # it worked, my goodness. Hang on, what has happened? Now I've got a message up here. (ENTER pressed here	#Language: interpretation (D N- <Interpreted OUTPUT as implying <correct solution
10:20:55: <AVG:AGE;> - ILLEGAL MONADIC OPERATOR 10:21:00: MESSAGE ID I18 State: Prompt with blank field	
Section 1.3.3 S: Illegal monadic operator. # I don't know whether that's a mistake for nomadic or not...	#Language: Interpretation (D N+

Key to System and Task Characteristics (Specific to system under analysis; may require modification as application changes.)

- The workplace environment: Comfort, lighting and noise.
- The terminal keyboard: Keying errors, confusions and delays.
- The terminal display: Legibility and formatting.
- General system operating characteristics: Control of the terminal, system response time, allocation of space.
- The interactive language: Lexical, syntactic and semantic.
- The interactive language: Interpretation of system responses.
- Task organization influenced by the system: Imposed goal structures.
- Task organization independent of the system: Conditions of the study.

Key to Symbols Used in Protocol Observations

\# = event categorizations
  (e = errors
  (d = difficulties
  (r = reminiscences
    M+ = created system error message
    M- = no system message generated
    N+ = noted by user before or when occurred
    N- = unnoted by user
< = explanatory comments
State = definition of system state after a user input

correct key was pressed but in the wrong shift. Subjects identified this as a problem: "I definitely think the worst thing about this is the amount you have to use the shift key." This is clearly an issue that could have been discovered at the design stage had an evaluative study been performed. The probable remedy would lie in changing the character set.

The chronicled events can also provide input for Hypothesis Generation of models. One model, termed Block Interaction Model, analyzes the separable classes of knowledge in the user's head which he draws upon during the interaction. Classes of knowledge include his representation of the problem, knowledge of the system, general knowledge of other systems, natural language, and so on. Note that this differs from the categorization scheme which deals only with system knowledge. The Block Interaction Model defines the possible forms of interference between the classes of knowledge.

A Goal Structure Model allows representation of the planning behind a sequence of dialogue and predicts the occurrence of certain classes of error at certain stages in the dialogue. Likewise, the user's internal representation of the state of the machine and how it changes with user actions can be contrasted with the true state of the machine by means of representation derived from a State Transition Model. The identification of system states particularly prone to error has consequences for the type of feedback that the system should present to the user, for example, which states should be defined by display flags.

The Information Processing Model calls upon current models in cognitive psychology dealing with relevant processes, such as language analysis and production, information storage and retrieval, and keyboard skills. A prediction of information storage models is that an item which is confusable with other items or which cannot easily be discriminated from them will be difficult to use and remember. Multiple use of the same character for different purposes is an example of a potential source of confusions which could be used to explore the model.

CONSTRAINTS

- System user must be capable of, and willing to, verbalize the reasoning associated with system usage.
- Requires interpretation by the researcher of system users' verbal reports.
- User reports may be incomplete; information which is obvious to user may not be verbalized.
- Possibility exists that problem-solving may be affected by concurrent verbalizations (Ref. 5).
- Tasks to be performed by system users will be determined by the purpose of the study.
- Observational studies on existing system should not be used as substitutes for considering human factors principles in the design.

KEY REFERENCES

1. Bainbridge, L. (1979). Verbal reports as evidence of the process operator's knowledge. International Journal of Man-Machine Studies, 11, 411-436.
2. Hammond, N. V., Long, J. B., & Clark, I. A. (1978). Introducing the interactive computer at work: The users' views. Proceedings Workshop on Computing Skills and Adaptive Systems, Liverpool, 127-144.

*3. Hammond, N., Long, J., Clark, I. Barnard, P., & Morton, J. (1980). Documenting human computer mismatch in interactive systems. Ninth International Symposium on Human Factors in Telecommunications.

4. Morton, J., Barnard, P. J., Hammond, N. V., & Long, J. (1979). Interacting with the computer: A framework. Teleinformatics '79, 201-208.
5. Newell, A., & Simon, H. A. (1972). Human problem solving. Englewood Cliffs, NJ: Prentice-Hall.

CROSS REFERENCES

6. Keystroke model for predicting task execution time; 8. Formal language as a design tool for person-computer dialogue; 9. Playback methodology for evaluating person- computer dialogue

*Principal reference

8. FORMAL LANGUAGE AS A DESIGN TOOL FOR PERSON-COMPUTER DIALOGUE

KEY TERMS

INTERFACE DESIGN; SYSTEM DESCRIPTION; GUIDELINE VERIFICATION; USER MODEL

GENERAL DESCRIPTION

The use of formal grammar as an analytic, predictive tool to aid man-machine interface design is enhanced by defining the concepts involved, making explicit the prediction process, and reducing limitations of predictions. The incorporation of "cognitive" information into the grammar permits differential system description for various classes of users. The prediction process includes assumptions which allow incorporation of psychological literature to expand the limits of prediction.

Figure 3 depicts the language used to describe user actions. Two kinds of actions are considered: information-seeking actions (both cognitive and physical) and physical input actions (observable inputs to the system). The examples shown label the two actions with the symbols "c" for cognitive or "i" for input.

An overview of the prediction process is presented in Table 9. Grammatical models (Step 1) do not deal with experimentally verifiable terms. Conversion is accomplished by rewriting terminal symbols to a new grammar using units of time or error (Step 2). For example: "<move cursor>": = $t_{move\ cursor}$. This accomplishes sentences with which comparative predictions can be made.

To make specific comparisons, the sentences corresponding to the comparisons to be made are derived from the grammar. For example, to compare system use by different user classes, the possible retrieval sources (e.g., book, human memory) are represented as alternations ("OK's") in the cognitive rules in the grammar. In deriving the sentences corresponding to each class of user, information seeking action which is appropriate to that class of user is selected. Thus, a naive user might be expected to use an external source (e.g., book), while an experienced user could retrieve this information from his own memory.

To make the prediction process explicit and powerful, the Assumptions on which the predictions are made must also be explicit and quantifiable (Step 4). These Assumptions are made from common sense and the experimental findings of human factors and psychology. Assumptions are written as inequalities or other equations, such as: Time to retrieve information from an external source (e.g., book) will be greater than time to retrieve from human long-term memory, i.e., ($t_{ext} > t_{LTM}$).

For a particular sequence of keystrokes, time to type the sequence, for users who type at the same typing speed, will be the same.

COGNITIVE TERMINAL SYMBOL

Example:

<delete line>::=

INFORMATION-SEEKING ACTIONS

<c-find out how to delete line>[1]::=
<c-retrieve from human memory>
<c-retrieve from external source>

<c-retrieve from human memory>::=
<c-retrieve from long term memory>
<c-retrieve short term memory
<c-use muscle memory>...

<c-retrieve from external source>::=
<c-retrieve from book>
<c-ask someone>...

+

PHYSICAL INPUT ACTIONS

<i-delete line>[2]

[1]c = cognitive action

[2]i = input action

Figure 3. Elements of user action language.

TABLE 9. ELEMENTS OF THE PREDICTION PROCESS

1.	An action grammar describing both cognitive and input actions.
2.	Extensions to the grammar to convert these actions to time or errors.
3.	Sentences derived from the grammar for particular tasks and classes of users.
4.	A set of Prediction Assumptions drawn from common sense, Psychology and/or Human Factors.
5.	Substitutions from the appropriate assumptions into the sentences to be compared, and solution according to the normal rules of simple algebra.

Interrelationships between them can also be made explicit. For example, if it is assumed that (1) time to find information in an external source is much greater than time to perform a typing action, and that (2) time to perform a typing action is greater than time to retrieve information from human memory, the order between the three quantities is obvious.

Predictions are made (Step 5) by algebraically solving the quantified terminal statements and prediction assumptions.

APPLICATIONS

Formal description of user interfaces; general analytic and predictive design aid.

Method of Application

For example, suppose predictions are to be made about naive versus skilled users whose typing speeds are equivalent. Two sentences from the grammar would be derived, one for each of the user classes. The "cognitive" and the "input" actions would be converted to variables representing times. The "sentences" for the two classes would differ. The "input actions" would be the same, but the information seeking actions would differ. The naive user would rely on the external source (e.g., book); the experienced user would rely on his/her human memory. The Prediction Assumptions would tell us that time to retrieve from an external source is greater than time to retrieve from human memory. Therefore, a prediction would be made that corresponds to our intuition. From the prediction process, we would predict that naive users would take longer on this task.

EMPIRICAL VALIDATION

Validation of the approach is ongoing. The validation methodology involves predictions and experimental results which are being made by separate individuals.

CONSTRAINTS

- Some of the Predictive Assumptions, if not all, will appear to be too simple. Their importance to the model is paramount; explicitly stated assumptions allow analysis and resolution of crucial or controversial issues.
- "Cognitive" assumption`s can be treated in a variety of ways to draw upon the literature. Broad familiarity with psychological literature, however, is required.

KEY REFERENCES

1. Reisner, P. (1982). Formal development toward using formal grammar as a design tool. In Proceedings of Human Factors in Computer Systems (pp. 304-308). New York: Association for Computing Machinery.

CROSS REFERENCES

6. Keystroke model for predicting task execution time; 7. A protocol analysis for documenting user problems with interactive systems

9. PLAYBACK METHODOLOGY FOR EVALUATING PERSON-COMPUTER DIALOGUE

KEY TERMS

SYSTEM EVALUATION; USER PERFORMANCE; VALIDATION

GENERAL DESCRIPTION

Playback is a general purpose data collection program to evaluate user performance with person-computer interfaces. Measurements of ease-of-learning may include:

- Time to complete a training program
- Time to achieve a performance criterion
- Observed difficulty in learning a product
- User comments, suggestions, and preferences.

Measurements of ease-of-use after initial learning may include:

- Time to perform selected tasks
- Success in task completion
- Frequency of use of commands or language features
- Time spent locating information in documentation
- User comments, suggestions, and preferences.

Other measures of user problems could include:

- Inability to find information in documentation
- Frequency that each error message is encountered
- Frequency of use of on-line help
- Use of special assistance (simulated product support).

Apparatus:

Playback provides a method for unobtrusively measuring these variables and storing the data for post-hoc analysis. Figure 4 diagrams the playback system configuration. The interface logic box provides interception of keystroke-level user behavior for time-stamp and storage in the lab computer. Time is recorded to msec tolerances.

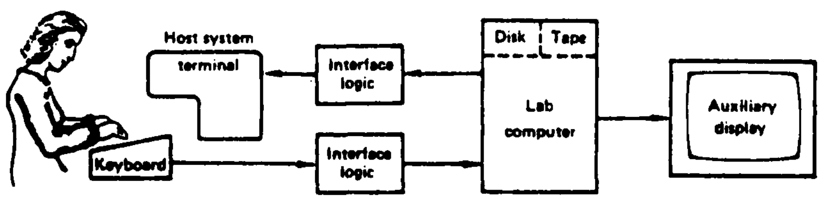


Figure 4. Schematic diagram of playback system. (Source: Neal & Simons, 1983)

The experimenter station (Figure 5) provides remote observation of user behaviors, on-line interaction with the software and the use of documentation. The experimenter records objective observations (codes and narrative comments) to supplement the keystroke-level data in the play-back analysis.

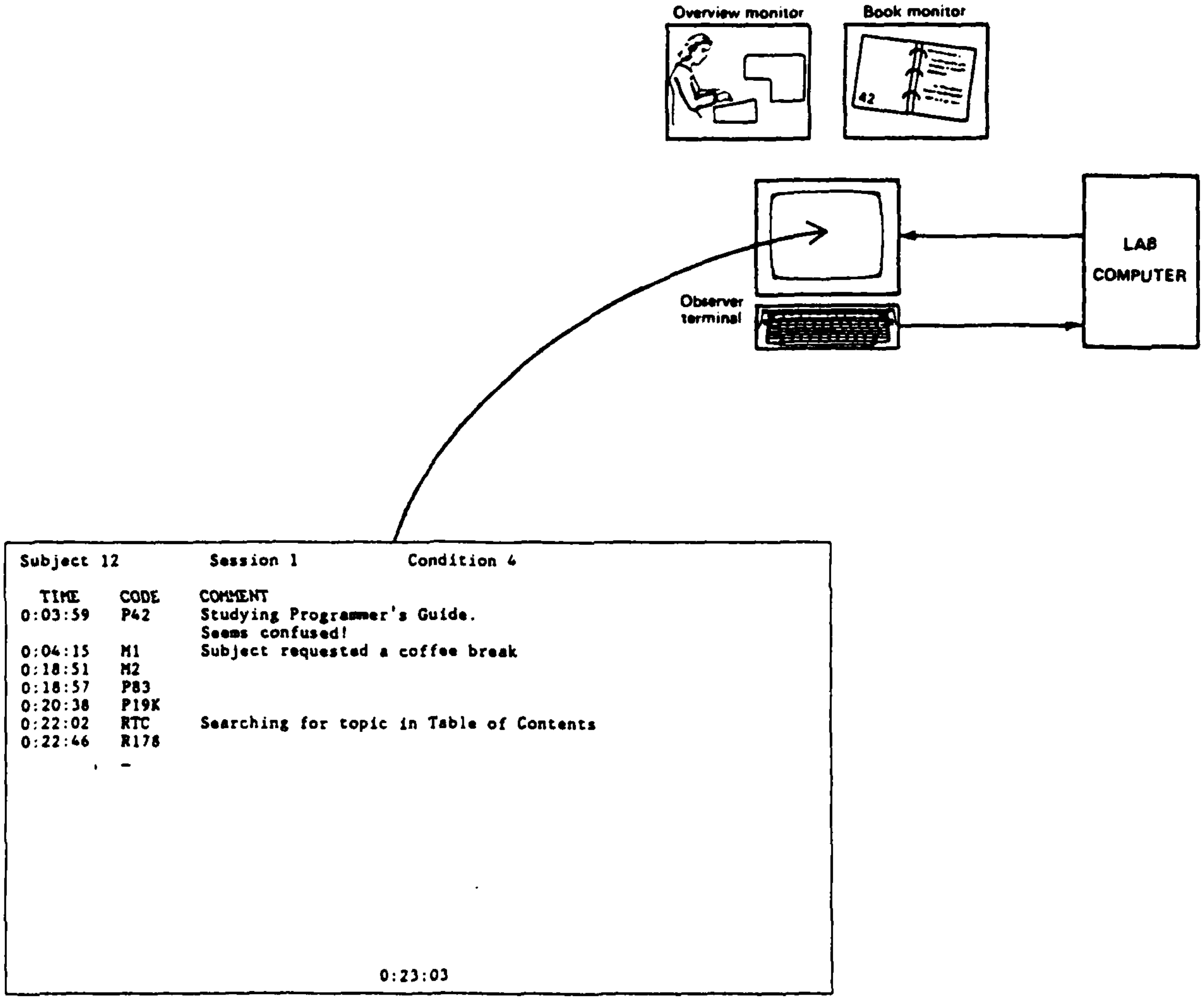


Figure 5. Experimenter station and sample of objective observations. (Source: Neal & Simons, 1983)

Analysis:

Playback analysis can be performed at various points of the data collection: after all of the required user sessions or after selected sessions. The playback software permits analysis of user behaviors by "playing back" sequences of user keystrokes in any of four pacing units selectable by the experimenter.

- Next character or function
- All characters up to and including the next interrupt
- All characters and functions up to and including the next interrupt
- All characters up to and including the next function with the same time intervals as when originally keyed by the user.

Figure 6 is a sample page of a playback analysis.

```
Subject 12            Session 1            Condition 4

0:20:30   CLEAR
0:20:55   A = (22/7) * R**2
0:21:20   ENTER                            Interval:  50 sec.

------------------------------ OBSERVATIONS ------------------------------

0:20:38   P19K
0:22:02   RTK         Searching for topic in Table of Contents

--------------------------------------------------------------------------

PF1: Next keystroke   PF2: Next function   PF3: Next interrupt
PF4: Real time        PF6: Set time        <--: Backup    CLEAR:  Abort

--------------------------------------------------------------------------

0:21:20   E5          Syntax error because referring to wrong page in
                      Programmer's Guide
```

Figure 6. Example of a playback screen. (Source: Neal & Simons, 1983)

Pacing units can be changed at any point in the analysis and sequences of interest can be repeated at will. During the playback analysis, the experimenter can further annotate user behaviors, as during data collection.

The playback software computes and records the following objective statistics for each session:

- Time from session beginning until user's first keystroke

- Time from session beginning until user's last keystroke
- Cumulative time in a "Help" condition
- Frequency of use of each function key
- Number of requests for help
- Frequency of use of selected commands.

APPLICATIONS

Dialogue simulation experiments; design of new person-computer dialogue; troubleshooting problem dialogue.

CONSTRAINTS

- Validation of playback methodology has not been published in the literature which has been reviewed.
- Playback provides analyses of terminal protocol and observed incompatibilities only; does not provide systematized:
  - Collection of verbal protocols
  - Modelling of cognitive incompatibilities
  - Generalization of models and hypotheses.
  - Analysis of results, including:
    - The workplace environment: Comfort, lighting and noise
    - The terminal keyboard: Keying errors, confusions and delays
    - The terminal display: Legibility and formatting
    - General system operating characteristics: Control of the terminal, system response time, allocation of space
    - The interactive language: Lexical, syntactic and semantic
    - The interactive language: Interpretation of system responses
    - Task organization influenced by the system: Imposed goal structures
    - Task organization independent of the system: Conditions of the study
    - Amount of data obtained may be overwhelming.

KEY REFERENCES

*1. Neal, A. S., & Simons, R. M. (1983, December 12-15). Playback: A method of evaluating the usability of software and its documentation. In Janda, A. (Ed.) Proceedings of CHI-83 Human Factors in Computing Systems (pp. 78-82). New York: Association for Computing Machinery.

2. Hammond, N., Long, J., Clark, I. Barnard, P., & Morton, J. (1980). Documenting human-computer mismatch in interactive systems. In Ninth International Symposium on Human Factors in Telecommunications.

CROSS REFERENCES

1. Steps in person-computer dialogue design; 6. Keystroke model for predicting task execution time; 7. A protocol analysis for documenting user problems with interactive systems; 8. Formal language as a design tool for person-computer dialogue

---

*Principal reference

10. INTERFACE DESIGN PRINCIPLES DERIVED FROM HUMAN ERROR ANALYSES

KEY TERMS

DESIGN GUIDELINES; COGNITIVE ENGINEERING; HUMAN ERROR; MODE ERRORS; DESCRIPTION ERRORS; CAPTURE ERRORS; ACTIVATION ERRORS

GENERAL DESCRIPTION

Analyses of the frequency, cause, and consequence of user errors provide information for designing more effective user-machine interfaces. Error analysis cannot address all classes of problems and should be supplemented with analyses of the user's mental model of the system and the human information processing capabilities of the user.

A general analysis of human errors, both in everyday events and in usage of computer systems, yielded the taxonomy of human errors given in Table 10. For selected error types, Table 11 presents the general cause of the error, an example, and preventative/corrective actions. The design rules follow the general principles of providing feedback to users, use of distinctive command sequences, protection against inadvertent activation of critical or fatal actions, and consistency.

APPLICATIONS

Design of man-machine interfaces; design of person-computer dialogue; design and layout of controls; design and layout of displays.

CONSTRAINTS

- o These data form only the early stages of a "cognitive engineering" discipline; further research will provide additional design principles based on cognitive theory.
- o These data summarize analyses of human performance and errors; incorporation of human information processing analyses and user's mental models will be needed for a well-rounded discipline.
- o Utilization of these data depend upon highly detailed knowledge of the user populations, man-machine interface, and error analyses.
- o This taxonomy of errors is only one of many which are available.

KEY REFERENCES

1. McFarland, R. (1973). Application of human factors engineering to safety engineering problems. In J. Widener (Ed.), Selected readings in safety. Macon, GA: Academy Press.

TABLE 10. CLASSIFICATION OF ERRORS (Source: Norman, 1983)

Slips in the Formation of Intention

- Mode errors: erroneous classification of the situation
- Description errors: ambiguous or incomplete specification of the intention

Slips Resulting from Faulty Activation of Schemas

- Unintentional activation: when schemas not part of a current action sequence become activated for extraneous reasons, then become triggered and lead to slips
- Capture errors: when a sequence being performed is similar to another more frequent or better learned sequence, the latter may capture control
- Data-driven activation: external events cause activation of schemas
- Associative activation: currently active schemas activate others with which they are associated
- Loss of activation: when schemas that have been activated lose activation, thereby losing effectiveness to control behavior
- Forgetting an intention (but continuing with the action sequence)
- Misordering the components of an action sequence, including skipping steps and repeating steps

Slips Resulting from Faulty Triggering of Schemas

- False triggering: a properly activated schema is triggered at an inappropriate time
- Spoonerisms: reversal of event components
- Blends: combinations of components from two competing schemas
- Thoughts leading to actions: triggering of schemas meant only to be thought, not to govern action
- Premature triggering
- Failure in triggering: when an active schema never gets invoked because:
  - Action was preempted by competing schemas;
  - There was insufficient activation, either as a result of forgetting or because the initial level was too low;
  - There was a failure of the trigger condition to match, either because the triggering conditions were badly specified or the match between occurring conditions and the required conditions was never sufficiently close.

TABLE 11. REDUCTION OF SELECTED ERROR TYPES (Source: Norman, 1983)

ERROR TYPE	CAUSE	EXAMPLE	PREVENTION/CORRECTION
Mode Errors	Lack of clear feedback as to current state	Computer text editor o issuing commands in text mode o entering text in command mode Pushing buttons on complex digital watches Entering data on auto-pilots of commercial aircraft	Provide more feedback and indication of current system state
Description Errors	When different actions have similar descriptions, either in specification of the action or in the class of argument Control panels without adequate distinctions among controls for quick glance or peripheral vision inspection	Multiple use keys in computer text editors (e.g., "d," "shift-d," "control-d") Throwing switches or operations of controls o altimeters o radio frequencies o transponder codes o nuclear power plant control rooms Derivation of unknown command structure by analogy with similar (known to user) command	Arrange instruments and controls in functional patterns Shape code controls for distinctiveness Make actions with critical implications difficult to perform Organize computer screens and menus functionally Design command language or menu headings to be distinct in appearance and required actions Consistency in command sequence formation
Capture Errors	Overlap in sequence required for performance of two different actions when one is more familiar than the other. Familiar act takes precedence over unfamiliar act	Berkley release of UNIX operating system write file option: :W = write file :Q = quit editor :WQ = write, then quit if :WQ is most frequently done and intention is to write and continue editing (:W), one may err and enter :WQ	Minimize overlap by using vastly different commands Determine critical points where errors occur and design system to flag or otherwise bring to operator's attention
Activation Errors	Inappropriate actions are performed Appropriate actions are not performed	Inappropriate action sequence activation resulting from relation to desired sequence Failure to perform action from memory failure	Provide memory aids Design system for tolerance of errors

2. Meister, D., & Rabideau, G. F. (1965). Human factors evaluation in system development. New York, NY: Wiley Publishers.

*3. Norman, D. A. (1983). Steps toward a cognitive engineering: Designing rules based on analyses of human error. In Janda A. (Ed.) Proceedings of CHI-83 Human Factors in Computing Systems: (pp. 378-382). New York: Association for Computing Machinery.

4. Rasmussen, J. (1978, November). Notes on human error analysis and prediction. Roskilde, Denmark: Riso National Laboratory.

5. Rigby, L. (1970). The nature of human error. Annual Technical Conference Transactions of the ASQC. Milwaukee, WI: American Society for Quality Control.

6. Singleton, W. T. (1977). Techniques for determining the causes of errors. Applied Ergonomics, 3(3), 126-131.

7. Swain, A., & Guttman, H. (1980). Handbook of human reliability analysis with emphasis on nuclear power plant applications. Albuquerque, NM: Sandia Laboratories.

CROSS REFERENCES

1. Steps in person-computer dialogue design; 20. Error recovery in person-computer dialogue

*Principal reference

11. TAXONOMY OF COMPUTER-USER CHARACTERISTICS

KEY TERMS

USER GROUPS; USER REQUIREMENTS; FRONT-END ANALYSIS

GENERAL DESCRIPTION

A frequently emphasized facet of interactive system design is knowledge of the user population. Precise description of the important variables, however, is left open to interpretation. The resulting actions are not often in accordance with what will be truly useful (Ref. 1).

"Know thy user" must go beyond mere identification and stereotyping of the user population, especially when these data are obtained through indirect means or logical conjecture. Without direct contact between designer and the user groups, underestimation of the diversity and capabilities of the user groups can occur. Interaction between designers and the users can provide invaluable insights into the differences between designers of systems and users of systems.

Table 12 lists 10 dimensions of users which should be considered by system designers. Although these characteristics cannot be linked directly to specific design guidelines, these data provide background information for design of systems compatible with the users.

APPLICATIONS

Front-end analysis of user characteristics; selection of dialogue type.

CONSTRAINTS

- Application of these data is limited by the depth/breadth and validity of the data collection.
- Variability of user populations on these dimensions may be extremely high in some application areas.
- Few user characteristics have been proven to be reliable predictors of performance with computers.

KEY REFERENCES

1. Gould, J. D., & Lewis, C. (1983). Designing for useability - Key principles and what designers think. In Janda, A. (Ed.) Proceedings of CHI '83 Human Factors in Computing Systems (pp. 50-53). New York, NY: Association for Computing Machinery.

*2. Nickerson, R. S., & Pew, R. W. (1977). Person-computer interaction. In Nickerson, R. S., Adams, M. J., Pew, R. W., Swets, J. A., Fidell, S. A., Feeher, C. E., Yntema, D. B., & Green, D. M., The C3 system user. Volume I (Report Number 3459). Cambridge, MA: Bolt, Beranek and Newman.

---

*Principal reference

TABLE 12. TAXONOMY OF INTERACTIVE SYSTEM USERS: SELECTED DIMENSIONS (Source: Nickerson & Pew, 1977)

- Knowledge or expertise as a computer programmer, systems analyst, computer operator, or other computer-related specialist.
- Knowledge concerning the specifics required for carrying out the job. What can be assumed concerning the user's understanding of how a particular application is to be carried out?
- The extent to which user's job or activity will focus on interactive terminal usage. Will he be using a terminal on a dedicated or casual basis? Will the terminal serve as an information source or as the basis for regular work performance?
- Level of decision-making authority and responsibility.
- Educational background.
- Availability of special skills or aptitudes such as clerical skills, managerial skills, mathematical skills.
- Expected duration of stay in particular job; employee turnover.
- Sources of job-related motivation. Is the user intrinsically motivated or must the interactive tasks be designed to promote motivation.
- Extent to which terminal usage will be an option versus a job requirement.
- Attitudes toward computer technology and its introduction in the work setting.

CROSS REFERENCES

1. Steps in person-computer dialogue design; 3. Comparison of approaches to person-computer dialogue

12. DESIGNING FOR THE CASUAL OR INFREQUENT COMPUTER USER

KEY TERMS

NAIVE USER; QUERY LANGUAGE REQUIREMENTS; DATABASE QUERY SYSTEMS

GENERAL DESCRIPTION

Design of data retrieval systems and dialogue for casual, novice, or infrequent users differs greatly from systems specifically intended for experienced or professional users. Designers must consider the consequences of infrequent use, including poor retention of system and training details. Productive design efforts will emphasize principles rather than details for effective user training. Error detection and correction functions can be guided by the system to combat the typical error-prone nature of an infrequent user's query. Casual users expect (and need, if maximum efficiency is to be attained) a system that feels "natural," i.e., corresponds with their "non-computer" dialogue perceptions. These include courteous, rational, and informative interactive dialogue which can also deal with the foibles of human dialogue. Human dialogue foibles include tolerance for imprecise logic or specifications, implicit or contextual references to previous queries, and requests for additional information. Failure to consider specifically the abilities and needs of the casual user can result in poor user performance due to extended time in training, increased error frequency and error recovery time, high amounts of inadvertently retrieved data, or extensive amounts of time negotiating the dialogue. Other results of inadequate dialogue design for the casual user can be reluctance or refusal to use the system. Table 13 presents selected guidelines for design of systems for casual users.

APPLICATIONS

Query language development; data base systems; management information systems.

CONSTRAINTS

- Requirements of casual users have not been subjected to extensive study.
- Most of the guidelines are not based on experimental studies; others are based loosely on empirical findings.
- Design must include numerous trade-offs if multiple user groups are anticipated and multiple dialogue types are not feasible.

KEY REFERENCES

1. Cuff, R. (1980). On casual users. International Journal of Man-Machine Studies, 12, 163-187.

CROSS REFERENCES

1. Steps in person-computer dialogue design

TABLE 13. SELECTED GUIDELINES FOR DESIGNING PERSON-COMPUTER DIALOGUE FOR THE CASUAL USER

DESIGN FOR A FORGETFUL USER

Train Users in Principles - Not Details
- Emphasize conceptualization of system as a whole
- Provide concise groundings in the principles of the interface
- Do not rely on existing skills in users

Provide Explicit, Constrained Choices for User Inputs:
- Use menu selection or prompting messages
- Make available choices apparent

Use "Natural Language" Interface for Communication on User's Terms.
Provide System Guidance to:
- Restrict queries within system competence
- Continue progression of a dialogue
- Supplement information presented in display, preferably on-line

MINIMIZE SYSTEM-PROVIDED OPPORTUNITY FOR USER ERRORS

Limit Number of Things User Must Consider at One Time
- Menu selection: 10 or less items; selection by consistent method
- Prompting systems: Restrict responses to well-defined range of values; utilize "query-in-depth" for system-initiated remediation of inappropriate responses

Include Corrective Features in System-Detected Errors
- Attempt prediction of user's intended entry
- Initiate sub-dialogues for clarification
- Describe corrective actions in error messages

Word Error Message for User Acceptance
- Use humble wording to retain user's goodwill
- Provide at least two alternately phrased messages

PROVIDE FEEDBACK FOR USER GUIDANCE AND REASSURANCE

Include Unambiguous System Responses for All User Entries For:
- Reinforcement of correct responses
- Error detection
- User identification of system actions

Use Dialogue Which Is Easily Understandable
- Avoid computer jargon
- Avoid unusual terms or abbreviations

Maintain a Natural Flow of Dialogue
- "Natural" ordering of questions and inputs

TABLE 13. SELECTED GUIDELINES FOR DESIGNING PERSON-COMPUTER DIALOGUE FOR THE CASUAL USER (Cont.)

MATCH DATABASE QUERY SYSTEM TO INFREQUENT USER'S ABILITIES

Reduce Data Structure, Content, or Semantics Knowledge Requirements

- Data should be requested by descriptive terms
- System should guide user through valid choices
- Requests by field (attribute) or record (relational) names should be minimal
- Names and descriptive phrases should be displayable upon user request
- When multiple logic paths occur, choices should be explained in user-oriented terms

Design for Deviations in Query Precision

- Anticipate vague, exploratory queries before precise questions
- Guard against excessive output from broad or erroneous requests, even if query appears legitimate
- If specific attributes of an entity are requested, consider supplying others to facilitate query formulation and data retrieval

Match Dialogue Language to the Needs and Abilities of Users

- Reduced language formality can facilitate casual users
- System aided syntax error detection/correction is desirable
- Implicit logic specification is less error-prone than explicit use of logical connectives and quantifiers
- Plan for logical errors in syntactically correct queries if explicit logic is required

13. SYSTEM RESPONSE TIME AND THE EFFECT ON USER PERFORMANCE AND SATISFACTION

KEY TERMS

SYSTEM RESPONSE INITIATION TIME; DISPLAY WRITING TIME; ARTIFICIAL LOCK-OUT; SYSTEM RESPONSE TIME VARIATION

GENERAL DESCRIPTION

Degradation in user performance is a non-linear function of system response time (SRT) when certain criteria are violated. Four major SRT categories and their characteristics have been identified (Refs. 2, 12, 13):

1. Greater than 15 sec.
   - Too slow for conversational dialogue
   - Free user from captivity of waiting for system
   - Allow user to get answer at own convenience
   - Message of expected delay is desirable

2. Five to 15 sec.
   - Too slow for interactive conversation
   - Frustrates users in problem solving and data entry activities
   - Allows unproductive behaviors or shifts to other task

3. Two sec.
   - Too slow for users at high concentration level

4. Almost instantaneous.

Variation in SRT can be as detrimental as long SRT's (Ref. 10). General recommendations are:

SRT	Maximum Variability
0-2 second	±5%
5 second	±10%
>5 second	±15%

Acceptable SRTs are dependent upon a user's expectations of system performance and perceived system activities to perform the task. Table 14 lists recommended SRTs and maximum variability for specific user activities/tasks. Reduction of SRT below the user's preparation time provides little or no performance advantage (Refs. 4 & 9).

APPLICATIONS

Interactive computer systems in which "conversational" dialogue, rather than on-line batch dialogue, is the intended mode. Situations where human performance and satisfaction are paramount to a system's successful mission or use.

TABLE 14. RECOMMENDED SYSTEM RESPONSE TIMES (Adapted from: Gallaway, 1981)

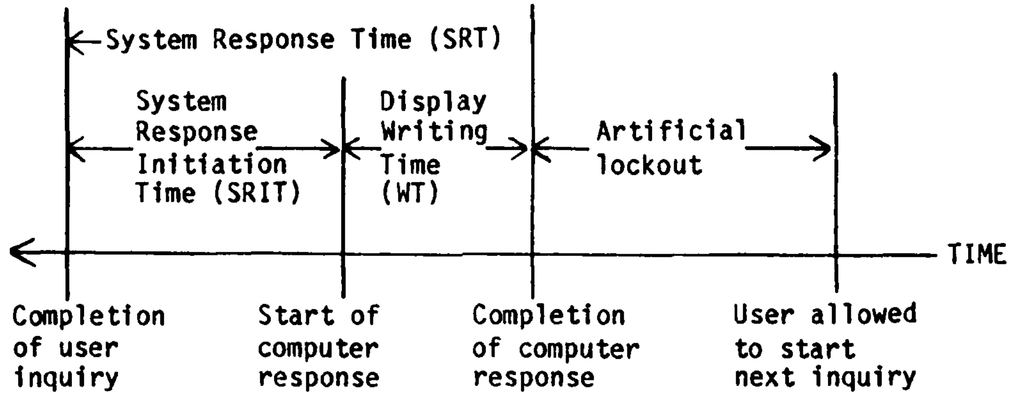
USER ACTIVITY/TASK	ACTIVITY/TASK EXPLANATION	MAXIMUM RESPONSE TIME (95 Percentile Occurrence)	RECOMMENDED TIME	TIME VARIABILITY ALLOWED FOR NO USER-PERCEIVED DIFFERENCE IN RESPONSE TIME
System Activation	User initializing a session with a terminal or other device.	3 sec	1 sec	± 10%
Request for Service	System availability and responsiveness to a user will depend on type and difficulty of work that must be performed.			
Simple Service	Routine single step operation. Example: Request for menu display page.	2 sec	.5 sec	± 10%
Complex Service	A multiple section or step task where a number of operations must be performed. Example: Send message (transmission/line communication), process data, return message (transmission line communication), etc., etc.	5 sec		
Loading and Restart	Program and data loading called for by the user.	15-60 sec	<30 sec	± 15%
Information on Next Procedure--Interactive Conversational Mode	Conversational interaction with a terminal requesting next step or procedure in a computer aided or guided task.	<5 sec		± 10%
Information on Next Procedure--One Part of a Multi-Part Job	Factory worker, etc. requesting next job assignment (non-dedicated terminal operation).	10-15 sec		± 15%
Response to Simple Inquiry from List	Query addresses existing record or record-string which can be directly retrieved and displayed. Example: Give physical description of part # 12345678.	2 sec		± 10%
Response to Simple Status Inquiry	Ask for one category of information about an unambiguously identified object. If system may have to do some searching and processing to assemble response, delay may be extended to 7-10 seconds. User must be informed of delay at start of processing delay.	2 sec (7-10 sec)		± 10%
Response to Complex Inquiry in Table Form	Requires collecting and displaying data on the basis of logical relationships among categories. It assumes an "image" of the displayed response does not pre-exist in the system.	2-4 sec (7-10 sec)		± 10%
Response to Request for Next Page	When text or data is continued from page to page, the time delay for the first few lines on the new page should be under 1 second.	.5-1 sec	.5 sec	± 5%
Response to Execute Problem	Longer response delays will initiate users to move to secondary tasks not directly related to the terminal.	<15 sec	<15 sec	
Response to User Intervention in Automatic Process	System response to user that the user command has been received and will be executed.	4 sec		± 10%
Error Feedback (following completion of input)	User input errors detected by the system or application being brought to the user's attention. Response time does not apply to hardware related or processing errors.	.5-2 sec	1 sec	± 10%

TABLE 14. RECOMMENDED SYSTEM RESPONSE TIMES (Source: Gallaway, 1981 (Cont.)

USER ACTIVITY/TASK	ACTIVITY/TASK EXPLANATION	MAXIMUM RESPONSE TIME (95 Percentile Occurrence)	RECOMMENDED TIME	TIME VARIABILITY ALLOWED FOR NO USER-PERCEIVED DIFFERENCE IN RESPONSE TIME
Response to Control Activation	Hardware related detection and operation response to user activities such as a signal that key depression, credit card read, forms insertion, has physically activated the device.			
Key Activation (alpha/numeric and control keyboards).	Response or feedback of physical key operation (such as key bottoming sound) should be immediate since high speed operation of keys may occur 10 msec apart in bursts.		<10 msec	
Hard e Response to Credit Card Opera on or Forms Insertion Operation	Response or feedback indicating only that a card or form has physically activated the hardware. Response may be auditory click, or visual or tactile signal that user activity has been noticed by the machine.	.4-.5 sec	.1 sec	Should be fixed
System Acceptance Response to Control Activation	System response to a user activity which means that a processor, etc. has been informed of the user activity and is responding with a signal of acceptance, rejection, proceed to next task, etc.			
Key Activation Acceptance (alpha/numeric and control keyboards)	Feedback of key operation being accepted by the system (buffer, processor, etc.) should be perceived as immediate since high speed operation of keys may occur 10 milliseconds apart in bursts.	May vary depending on application	<30 msec	
Response to Credit Card Operation or Forms	Response or feedback indicating proper or improper card or forms by the system. Also could indicate that this action has been completed and machine is ready for next user activity.	2-4 sec	1 sec	Should be fixed
Response to Light Pen Requests	Request for image or format by touching light pen to code name, code number, or display position.	1 sec	.5 sec	± 5%
Drawings with Light Pen (used as stylus)	Drawing lines on display face where direction and shape of line have significance and movements are relatively slow.	.1 sec		± 5%
Light Pen Control Activation	Response to user activation of pen switch indicating that switch has operated.	.1 sec	.1 sec	± 5%

CONSTRAINTS

- System response time definition (Ref. 10):



- Artificial lockout may improve complex problem-solving performance but reduces user satisfaction (Refs. 1, 6, & 12).
- Effects due to display writing time have not been adequately researched.

KEY REFERENCES

1. Boehm, B. W., Seven, M. J., & Watson, R. A. (1971). Interactive problem-solving: An experimental study of "lockout" effects. AFIPS Conference Proceedings, 38, 205-210.
2. Carbonnell, J. R., Elkind, J. I., & Nickerson, R. S. (1968). On the psychological importance of time in a time-sharing system. Human Factors, 10, 135-142.
3. Eason, K. D. (1976). A task-tool analysis of manager-computer interaction. A paper presented at NATO Advanced Study Institute on Man-Computer Interaction, Mati, Greece. (Reprinted by Department of Human Sciences, University of Technology, Loughborough, Leicestershire, England.)
4. Franklin, J., & Dean, E. (1974, May-June). Some expected and not so expected reactions to a computer-aided design with interactive graphics (CANDIG) system. SID Journal, 5-6, 8, 11-13.

*5. Gallaway, G. R. (1981). Response times to user activities in interactive man/machine computer systems. In Proceedings of the 25th Annual Meeting of the Human Factors Society (pp. 754-758). Santa Monica, CA: The Human Factors Society.

6. Gold, M. M. (1967). A methodology for evaluating time-shared computer system usage. Unpublished doctoral dissertation, Massachusetts Institute of Technology, Cambridge, MA.
7. Miller, R. B. (1968). Response time in man-computer conversational transactions. AFIPS Conference Proceedings, 33(pt. 1), 267-277.
8. Morefield, M. A., Wiesen, R. A., Grossberg, M., & Yntema, D. B. (1969). Initial experiments on the effects of system delay on on-line problem solving (TN-1969-5). Cambridge, MA: Massachusetts Institute of Technology, Lincoln Laboratories.

---

*Principal reference

9. Newman, W. M. (1969). Interactive graphical response and its effects on display system performance. In Proceedings of the International Symposium on Man-Machine Systems, 4 (IEEE Conference Record No. 69C58-MMS). New York, NY: Institute of Electrical and Electronics Engineers, Inc.
10. Ramsey, H. R., & Atwood, M. E. (1979). Human factors in computer systems: A review of the literature (Technical Report SAI-79-111-DEN). Englewood, CO: Science Applications, Inc. (NTIS AD A075 679)
11. Seven, M. J., Boehm, B. W., & Watson, R. A. (1971). A study of user behavior in problem-solving with an interactive computer (R-513-NASA). Santa Monica, CA: Rand Corp.
12. Simon, H. A. (1966). Reflections on time sharing from a user's point of view. Science Research Review, 43-51.
13. Williams, J. D. (1975). The effects of computer subsystem response time and response time variance on operator performance in an interactive computer system. Paper presented at meeting of the American Psychological Association, Chicago, IL.

CROSS REFERENCES

1. Steps in design of person-computer dialogue; 36. Guidelines for use of non-critical auditory signals

14. INFORMATION BANDWIDTH IN PERSON-COMPUTER DIALOGUE

KEY TERMS

DIALOGUE POWER; EASE OF USE; MULTIPLE PURPOSE DIALOGUE

GENERAL DESCRIPTION

In designing dialogues for general usage, a trade-off must be made between ease of use and information bandwidth based on the characteristics of the user.

Information bandwidth, the quantity of information communicated, or decisions made in a given time, using a dialogue, is highly dependent on the efficiency of information encoding. Although some user types (professionals and managers) may require a high bandwidth of information, system acceptability may be low if the system is difficult to use. Highly desirable dialogues (large quantity of information and easy to use) appear in the upper left quadrant of Figure 7. The lower right quadrant includes dialogues to be avoided due to narrow application and dependence on highly proficient users.

The rate of change for variable data displays in the screen design must be limited, however, to maintain consistency with human information processing limitations. Suggested limitations include no more than a 1 Hz update of the most important dynamic information, and a limit of the proportion of dynamic data being displayed of 40% of the displayed parametric data (Ref. 1).

For higher information bandwidth displays, it is imperative to consider related variables such as coding, formatting and structuring of the data display.

APPLICATION

Selection of dialogue mode based on characteristics of the users' abilities/needs; multiple-application (general purpose) dialogue design.

CONSTRAINTS

- Information bandwidth is not necessarily proportional to physical channel bandwidth.
- For development of the figure, information bandwidth was subjective (estimate of number of basic assembler code lines equivalent to five min of dialogue).
- Efficiency of the dialogue does not predict the usefulness of dialogue.
- Major differences exist between easy-difficult and high-low information bandwidth dialogues.
- High flexibility or power (potentially desirable characteristic) may result in greater time to become proficient.

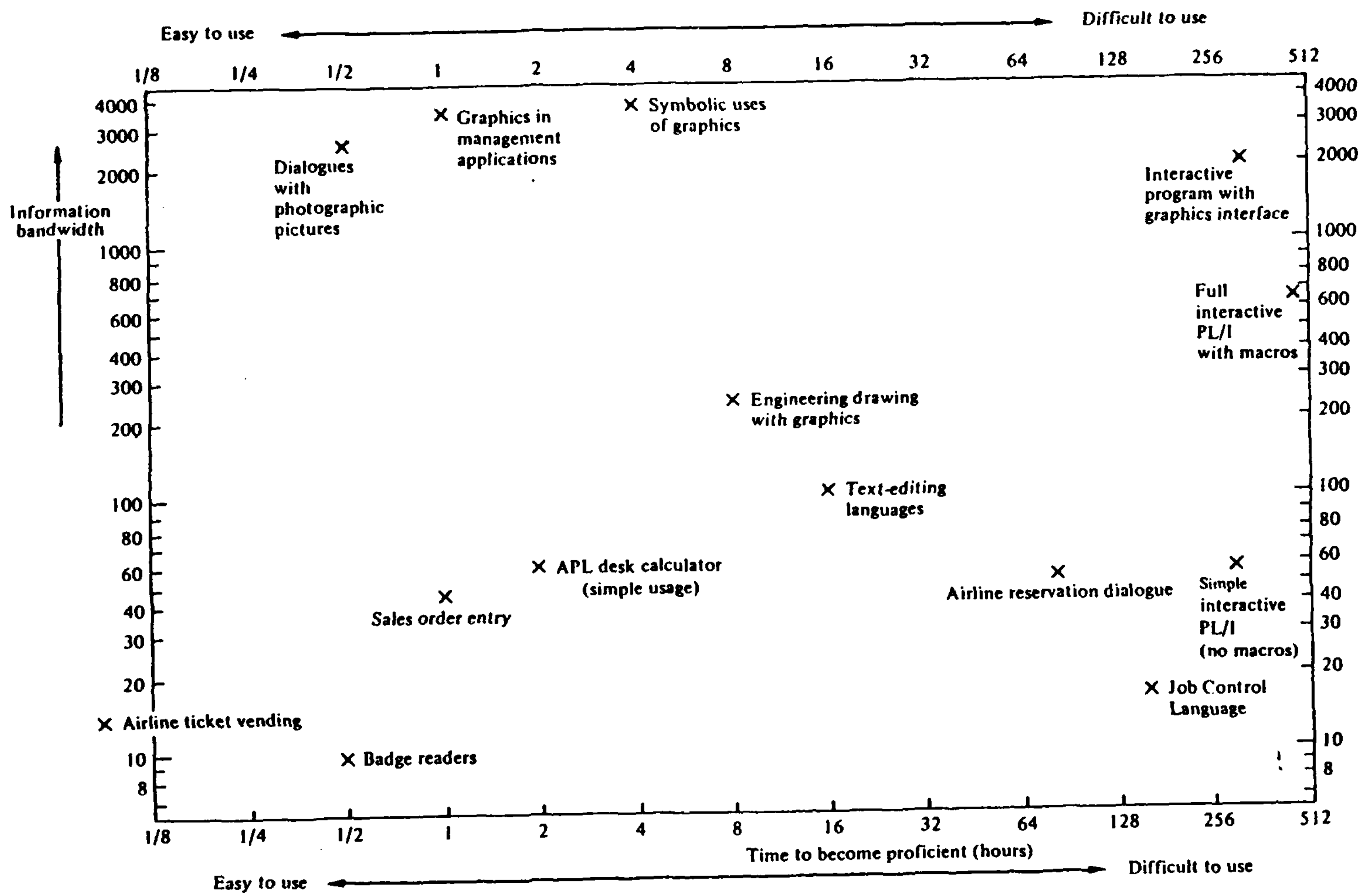


Figure 7. Dialogue power and ease-of-use. (Source: Martin, 1973)

- "Undesirable" dialogues may hold utilitarian value for specific or narrow applications.
- Easy to use/high information bandwidth dialogues can substantially increase the hardware, communications and programming complexity.

KEY REFERENCES

1. Hendricks, D., Kilduff, P., Brooks, P., Marshak, R., & Doyle, B. (1982). Human engineering guidelines for management information systems. Alexandria, VA: U.S. Army Materiel Development and Readiness Command.

*2. Martin, J. (1973). Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.

CROSS REFERENCES

25. Presenting numeric data in person-computer dialogue; 26. Presenting text data in person-computer dialogue; 27. Presenting tabular data in person-computer dialogue; 28. Graphics in person-computer dialogue; 29. Information coding in person-computer dialogue; 32. Screen layout and structuring of person-computer dialogue displays

---

*Principal reference

15. DESIGN RECOMMENDATIONS FOR QUERY LANGUAGES

KEY TERMS

QUANTIFIERS; MIXED INITIATIVE DIALOGUE; DATA ORGANIZATION; ABBREVIATIONS; NATURAL LANGUAGE; FORMAL QUERY LANGUAGE; INFORMAL QUERY LANGUAGE

GENERAL DESCRIPTION

Guidelines for the design of query languages have been derived from two types of research: (1) studies of the query behaviors of computer-naive users and attempts to facilitate query formulation in natural languages, and (2) usability studies of specific languages. Although relatively few studies compare across languages or across the entire process, errors emerging from these studies provide considerable insight into the kinds of logical constructions and query language features that represent difficulties for users.

Table 15 displays some known problem areas in the use of query languages. For each problem area, comments and references are provided. A collection of recommendations and guidelines, distilled from the literature (Ref. 1), are presented in Table 16. The recommendations specifically address the previously defined problem areas.

APPLICATIONS

Design of dialogue language; evaluation of query languages.

CONSTRAINTS

A number of questions which will provide important information to designers have not yet been researched (Ref. 3), including:

- Effects of frequency of use on query language choice.
- Amount of instruction required in other languages to achieve the same level of competence
- Degree of threat which formal query languages pose to potential users.
- The proportion of invalid or incorrect query statements which a user will tolerate prior to rejection of the language or system.
- Acceptability of a restricted subset of English as query language.

KEY REFERENCES

*1. Ehrenreich, S. L. (1981). Query languages: Design recommendations derived from the human factors literature. Human Factors, 23(6), 709-725.

2. Gould, J. D., & Ascher, R. N. (1975). The use of IQF-like query language by nonprogrammers (RC-5279). Yorktown Heights, NY: IBM Watson Research Center.

---

*Principal reference

TABLE 15. USER PROBLEMS WITH QUERY LANGUAGES (Source: Ramsey & Atwood, 1979)

PROBLEM AREAS	COMMENTS	REFERENCES
Logical Quantifiers	Use of logical quantifiers (all, some, none) in the presence of set relations (union, intersection, etc.) is very error-prone.	Ref. 5
Set Relations	When sets of elements are related in a complex way, human interpretation of the relationship is often erroneous.	Ref. 5
Logical Relations	Disjunction (logical "or") and negation are error-prone constructs. Although this finding is consistent with basic psychological research and is probably generally true, the principal study (Miller, 1974) in which it is related to programming and query language design involves an atypical task in which the subject must compensate for absence of these constructs in a language by devising a procedural specification using transfer of control.	Ref. 2
Arithmetic Relations	Conversion of inequalities (e.g., from "over 50" years old to "51 or more" years old) is error-prone. Also, users tend to use arithmetic relations even with "nominal" categories, as "college degree greater than or equal to B.S."	Ref. 2
Semantic Confusion of Commands	Errors occur when query language has confusable commands, such as COUNT ("how many numbers are there?") and TOTAL (what is their sum?).	Ref. 2
Use of Synonyms for File Names, Properties, etc.	Users tend to substitute synonymous terms (e.g., "employee" for "personnel" file) which system may not recognize.	Ref. 5
Misspelling	Spelling errors are common in query formulation. Also, users tend to use an incorrect ending (e.g., "employees" instead of "employee").	Ref. 2 Ref. 5 Ref. 6
Omission of Problem-Relevant Attributes	In formulating complex queries, users frequently omit one or more of the attributes which define the set.	Ref. 2 Ref. 6
Contextual Referencing	If unconstrained, users tend to make contextual references in queries. However, there is no clear evidence that users fail to adapt to query languages which preclude such references.	Ref. 3

TABLE 16. GUIDELINES FOR QUERY LANGUAGE DESIGN

GENERAL RECOMMENDATIONS

Data Organization

- o Match user's perception of natural organization
- o Use single representation of data

Quantifiers

- o Minimize use of quantification terms, except "NO" and "NONE"
- o When quantifiers are required
  - Design quantifiers for distinctiveness
  - Provide set of statements for user selection

Feedback of Query

- o Rephrase and display query before execution
- o Provide override option of this feature for experienced users

Abbreviations

- o Truncate to form abbreviations, except commonly known abbreviations
- o Three to five characters in length
- o All abbreviations must be unique
- o User should know abbreviation logic

Dialogue Transaction

- o System messages should be in directly usable form
- o Provide prompts or reminders of current state of transaction development
- o All information for user determination of present system states should be in a single transaction
- o Periodically recap lengthy sequences of transactions
- o Information should be in the form immediately needed
- o Queries which are frequently used should be easy to conduct
- o Feedback should include receipt of query and anticipated response time

SPECIAL RECOMMENDATIONS - FORMAL QUERY LANGUAGES

Layering

- o Language features should be partitioned into groups or layers
- o Easiest layer should stand alone and be intended for casual users
- o Layers should increase in complexity for more sophisticated users

Semantic Confusion

- o Avoid operators such as "or more" and "or less"
- o Operators should be given semantically similar names
- o Names of operators should be unique and self-explanatory

Term Specificity

- o Global terms are not recommended for beginning users, except where globally described data are retrieved together frequently

SPECIAL RECOMMENDATIONS - INFORMAL QUERY LANGUAGES

Clarification Dialogue

- o System should clarify poorly-stated queries rather than reject them
- o Systems should guide user in formulation of properly stated query

Quasi-Natural Language

- o Requires narrow and well-defined systems task

3. Miller, L. A., & Becker, C. A. (1974). Programming in natural language (RC-5137). Yorktown Heights, NY: IBM Watson Research Center. (NTIS No. AD A003 923)
*4. Ramsey, H. R., & Atwood, M. E. (1974). Human factors in computing systems: A review of the literature (SAI-79-III-DEN). Englewood, CO: Science Applications, Inc. (NTIS AD A075 679).
5. Reisner, P. (1977). The use of psychological experimentation as an aid in the development of a query language. IEEE Transactions on Software Engineering, SE-3, 218-229.
6. Thomas, J. C., & Gould, J. D. (1975). A psychological study of query by example. AFIPS Conference Proceedings, 44, 439-445.

CROSS REFERENCES

2. Basic properties of person-computer dialogue; 3. Comparison of approaches to person-computer dialogue; 4. Major data models in data base systems; 12. Designing for the casual or infrequent user; 16. Comparison of query languages: query-by-example, SEQUEL, and algebraic language; 20. Error recovery in person-computer dialogue

* Principal reference

16. COMPARISON OF QUERY LANGUAGES: QUERY-BY-EXAMPLE, SEQUEL, AND ALGEBRAIC LANGUAGE

KEY TERMS

DATA BASE SYSTEMS; DATA BASE QUERY LANGUAGES

GENERAL DESCRIPTION

The relative learning and application capabilities of Zloof's query by example (Ref. 4), a structured English query language (Ref. 1), and a variation of Codd's Algebraic Language (Ref. 2) were compared. Training time, query time, query accuracy, and subjective confidence ratings were assessed (see Table 17).

Query formulation was found to be aided by the tabular format and the lower ambiguity of query-by-example than by the other languages. Query-by-example also displayed the least fairly-or-very-sure-incorrect ratings of the three languages (see Figure 8).

TABLE 17. COMPARISON OF THREE QUERY LANGUAGES: TIME, ACCURACY, AND SUBJECT CONFIDENCE (Source: Greenblatt & Waxman, 1978)

	QUERY BY EXAMPLE*	SEQUEL	ALGEBRAIC LANGUAGE
Training Time (hours:minutes)	1:35	1:40	2:05
Mean Total Exam Time (minutes)	23.3	53.9	63.3
Mean Correct Queries (%)	75.2	72.8	67.7
Mean Time/Query (minutes)	.9	2.5	3.0
Mean Confidence/Query (1 to 5)	1.6	1.9	1.9

*Highest confidence ratings

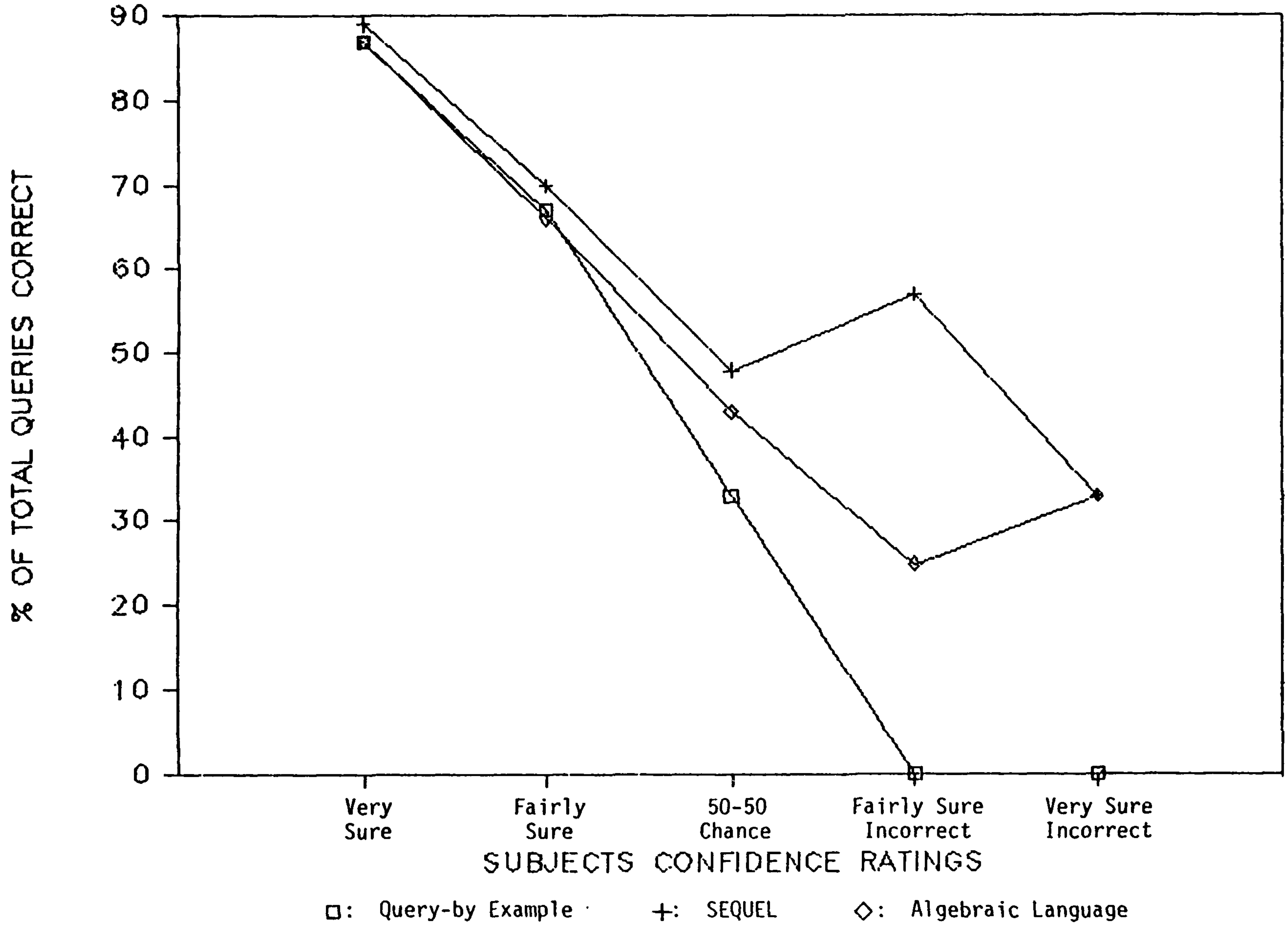


Figure 8. Confidence rating to correctness ratio.
(Source: Greenblatt and Waxman, 1978)

APPLICATIONS

Selection of query languages for casual or infrequent users; query language selection for systems where training time is severely limited; prediction of needs for query-in-depth user aids.

METHODOLOGY

Stimulus and Viewing Conditions

- Twenty-question exams translated into the three languages; o questions provided sample data base and sample queries.

Procedure and Experimental Design

- Independent variable: Query language.
- Dependent variables: Training time, exam time, percent correct queries, subjective ratings of confidence.
- Observers (Os) trained in languages by review of examples and instructor feedback.
- Three random O groups: Query by Example (n=7), SEQUEL (n=17), Algebraic Language (n=13).

EXPERIMENTAL RESULTS

- No statistically significant difference was found in mean exam time and mean correct queries among the three languages due to large standard deviations.
- Confidence ratings were statistically significantly higher for query by example, but not for SEQUEL or algebraic language.

CONSTRAINTS

- The query languages compared differ considerably in basic philosophy and in details of dialogue.
- The present study only addressed part of the query process: encoding the query. The overall process includes: (1) information need, (2) question formulation, (3) approach planning, and (4) query encoding.

KEY REFERENCES

1. Chamberlin, D. D., & Boyce, R. F. (1974). SEQUEL: A structured English query language. Proceedings of the Association of Computing Machinery Sigfidet Workshop, Ann Arbor, MI, 249-264.
2. Codd, E. F. (1970). Relational model of data for large shared data bases. Communications of the Association of Computing Machinery, 13(6), 337-387.

*3. Greenblatt, D., & Waxman, J. (1978). User-oriented query language design. In Proceedings of Human Factors and Computer Science (pp. 79-102). Santa Monica, CA: Human Factors Society.

---

*Principal reference

4. Zloof, M. M. (1974). Query by example (RC 4917). Yorktown Heights, NY: IBM, T. J. Watson Research Center.

CROSS REFERENCES

1. Steps in person-computer dialogue design; 15. Design recommendations for query languages

17. DATA ENTRY DISPLAYS

KEY WORDS

DATA FORMS; GUIDANCE MESSAGES; FIELD LABELS; FORM-FILLING DATA DISPLAY; DATA INPUT; SEQUENCE CONTROL; USER-COMPOSED DATA ENTRY

GENERAL DESCRIPTION

User-composed data entry provides a more flexible means of input than some of the more limited dialogue types, such as menu selection. Greater variability in user performance (input and error rates) results from this flexibility, especially among infrequent and novice users. Table 18 provides a set of guidelines for selection of codes, design of data fields, and use of labels for optimizing user performance in data entry tasks.

APPLICATIONS

Data entry tasks; form-filling dialogue; computer-initiated dialogue.

CONSTRAINTS

- o Guidelines may not be generalizable to all applications.
- o Some user controlled flexibility may increase efficiency, such as user pacing of data input, control of input sequence, or definition of default values.
- o Design of data entry transactions is highly dependent on hardware design/selection.
- o Guidelines may not be based on data from empirical research.

KEY REFERENCES

1. Smith, S. L. (1980). Requirements definition and design guidelines for the man-machine interface in C3 systems acquisition. (ESD-TR-80-122). Bedford, MA: MITRE Corp.

*2. Smith, S. L., & Aucella, A. F. (1983). Design guidelines for the user interface to computer-based information systems (ESD-TR-83-122). Bedford, MA: MITRE Corp.

CROSS REFERENCES

12. Designing for the casual or infrequent computer user; 13. System response time and the effect on user performance and satisfaction; 19. Sequence control in person-computer dialogue; 25. Presenting numeric data in person-computer dialogue; 27. Presenting tabular data in person-computer dialogue; 30. Abbreviations and acronyms

---

*Principal reference

TABLE 18. GUIDELINES FOR DESIGN OF DATA ENTRY DISPLAYS
(Source: Smith & Aucella, 1983)

Design Objectives

- Establish consistency of transactions
- Minimize input actions
- Minimize memory load on user
- Ensure compatibility of data entry with data display
- Provide flexibility of user control of data entry

Minimal Keying for Character Entry

- Alphanumeric entries should be single stroke of labeled keys
- Minimize double-keying for special characters
- Automatic entry of leading zeros should be optional
- Eliminate distinction between single and multiple blanks

Implicit Prompting for Data Field Delineation

(Good)	(Bad)
LICENSE NUMBER: _ _ _ _ _ _ _ _	ENTER LICENSE NUMBER:
MAKE:	ENTER MAKE (14 characters):
YEAR/MODEL:	ENTER YEAR/MODEL (11 characters):

- Mark fields with special characters
- Visually indicate fixed or maximum acceptable entry
- Distinguish required and optional entries
- Automatically justify entry and remove unused underscores
- Provide tab keying between fields

Logical Format of Data Fields

- Data entry display should be compatible with output display
- Data entry display should match source document format
- Entry should follow logical sequence if no source document exists
- Users should not have to enter data twice

TABLE 18. GUIDELINES FOR DESIGN OF DATA ENTRY DISPLAYS (Cont.)
(Source: Smith & Aucella, 1983)

Clear Labeling of Data Fields

(Good)	(Bad)
Week: ____ Month: ____ Year: ____	DACODE: _ _ _ _ _ _ _ _ _ _
Social Security Number: ___-__-____	SSAN: _ _ _ _ _ _ _ _ _ _ _
Speed Limit: ______ MPH	LIM: _ _ _ ft. per second
Distance: ________ (km/hr) ________	DIST (4 chars and unit) _ _
Cost: $______	COST: _ _ _ _ _ _ _

- Use agreed terms, codes, or abbreviations only
- Separate label from field with an exclusive punctuation character
- Include data format cues where applicable
- Fixed measurement units - display in label
- Variable measurement units - provide alternatives and space for user entry
- Use units of measurement which are familiar to user
- Do not require user to do any data conversions

18. COMPARISON OF INPUT TIME AND ERRORS BETWEEN POINT-IN AND TYPE-IN DATA ENTRY

KEY TERMS

INPUT ERROR; LIGHTPEN; JOYSTICK; ROLLING BALL; KEYBOARD

GENERAL DESCRIPTION

This experiment measured the relative efficiency of type-in (keying) and point-in (pointing) data entry methods in terms of input speed and accuracy. The number and kind of errors committed under the two methods were analyzed. Analyses of both input time and errors indicated statistically significant main effects of input task, word density and typing ability. Table 19 provides comparisons on input time for all levels of these variables. Tasks consisting of searching displays for words and typing words not displayed take longer to perform than either tasks consisting of searching and detecting displayed words or simply typing the words. Entry time increased with lower typing skills and higher word densities.

Error frequencies, categorized by type, are presented in Table 20. Statistical comparison of errors for all levels of the three significant main effects are presented in Table 21. Mean error in the point-all words task was smaller than under all other task conditions. Mean error under the point-zero type-three and type-all words tasks was significantly lower than the mean error for the remaining input tasks.

Significantly fewer errors were made under the six word density level than under the other three density levels, and more errors were committed under the 18 word level than under the other three density levels.

Omission errors were committed less frequently than the other error types, while more detection errors were made than any other error type. Fewer substitution errors were made than either typographical or detection errors. No significant differences in the incidence of redundancy, misperception, or typographical errors were found.

The overall major findings included:

- No significant difference in input time between point-all and type-all methods, but the input error rate (one error per every 133 words entered) for the point-all task was one-seventh the error rate (one error per every 18 words entered) of the type-all task.
- Data input by the type-in method resulted in typographical and misperception errors. Both of these error types were eliminated when using the point-in method.
- An increase in word density inhibited input performance by increasing input time and error rate. The bulk of the error increase was the result of a large increase in detection errors.
- Comparison of the point-all and type-all conditions with the three actual mixed input tasks showed that the factor of certainty of input method, i.e., more information, enhanced performance.

TABLE 19. MEAN INPUT TIME DIFFERENCES BETWEEN LEVELS OF THE MAIN EFFECTS* (Source: Earl & Goff, 1965)

(a) Input Tasks

Point-all	Point-3 Type-0	Type-all	Point-2 Type-1	Point-1 Type-2	Point-0 Type-3
6.58	7.13	7.50	10.32	12.34	12.57

(b) Word Density

6 Words	10 Words	14 Words	18 Words
9.87	11.13	13.20	14.74

(c) Typing Ability

Good	Fair	Poor
7.33	8.37	8.76

*Levels of the factors connected by rule are not significantly different at $p<0.01$.

TABLE 20. FREQUENCY OF POINT-IN AND TYPE-IN ERRORS LISTED BY ERROR TYPE (Source: Earl & Goff, 1965)

CLASSES AND TYPES OF ERRORS	N ERRORS	% OF TOTAL ERRORS
Point-in Errors		
Detection	300	41.0%
Substitution	24	3.3%
Omission	3	0.4%
Total Point-in Errors	327	45.1%
Type-in Errors		
Omission	4	0.5%
Redundancy	116	16.0%
Misperception	113	15.6%
Typographical	164	22.6%
Total Type-in Errors	397	54.9%
Total Errors	724	100.0%

TABLE 21. MEAN ERROR SCORE DIFFERENCES BETWEEN LEVELS OF THE MAIN EFFECTS* (Source: Earl & Goff, 1965)

(a) Input Tasks

Point-all	Point-0 Type-3	Type-all	Point-3 Type-0	Point-2 Type-1	Point-1 Type-2
0.54	3.13	4.00	7.13	7.42	7.96

(b) Word Density

6 Words	10 Words	14 Words	18 Words
4.25	5.63	6.33	9.96

(c) Error Types

Omission	Substitution	Redundancy	Misperception	Typographical	Detection
0.29	1.00	4.70	4.83	6.83	12.50

*Levels of the factors connected by rule are not significantly different at p<0.01.

APPLICATIONS

Selection of input devices for data entry tasks in which entry time or errors are critical.

METHODOLOGY

Stimulus and Viewing Conditions

• Simulated data entry console consisted of IBM electric typewriter, two rear-projection source data screens, observer (O) ready light, and a simulated data entry knob; • randomized lists of unique 3 to 7 character words (printed console display formats and photographically projected source data sets); • four density levels: 6, 10, 14, 18 words per list; • five word arrangements: vertical, semi-vertical, proportional, semi-horizontal, horizontal.

Procedure and Experimental Design

- 5x6x4x3x2x2 complete factorial within subject design.
- Independent variables: Five data arrangements, 6 input tasks (point-in three and type-in zero words, point-in two and type-in one word, point-in one and type-in two words, point-in zero and type-in three words, point-in all three words, type-in all three words), four word densities, three typing abilities (Good: 32-73 words per min; Fair: 17-32 words per min; Poor: 15-17 words per min), sex (male, female), two relative locations of keypunch device to operator (typewriter on right, typewriter on left).

- Dependent variables: Input time (elapsed time per trial) and error scores (incorrect transcription of source data words coincident with input task).
- O read source word list from display screen; source words appearing on printed console display format were marked (point-in), unlisted words were input on keypunch device (type-in).
- 24 subjects tested twice in all conditions.

EXPERIMENTAL RESULTS

- Word arrangement and position of keyboard had no influence on performance.
- Input time: decreases as number of point-in words decrease in mixed tasks; decreases as word density decreases; decreases with good typing ability.
- Detection errors were most common (41% of all errors) followed by typographical (22.6%), redundancy (16%), and misperception (15.6%) errors.
- Errors: Are minimized in point-all tasks; decrease as word density decreases.

Reliability

. Input time: Input task and word density significant at .001 level of confidence; typing ability significant at .05 level. Error scores: Input task, word density, and error type significant at .001 level of confidence.

CONSTRAINTS

- Performance in mixed point-in/type-in tasks may increase if O is familiar with the words contained in the formats.
- Visually separate and partial feedback displays, as a function of input task type, were used; a unified feedback display may result in better performance.

KEY REFERENCES

1. Earl, W. K., & Goff, J. D. (1965). Comparison of two data entry methods. Perceptual and Motor Skills, 20, 369-384.

CROSS REFERENCES

17. Data entry displays

19. SEQUENCE CONTROL IN PERSON-COMPUTER DIALOGUE

KEY TERMS

USER INITIATIVE; EXPLICIT USER ACTIONS; FLEXIBILITY OF CONTROL; USER CONTROL

GENERAL DESCRIPTION

The logic and means of input and output linkage into coherent transactions, as well as control of interactive transactions should be designed to:

- Maintain consistency of control actions.
- Minimize control actions and user memory load.
- Be compatible with user and task needs.
- Allow flexibility of control by the user.

The degree and type of user control must be mediated by the type of task and the characteristics of the user. As a general rule, however, user control is preferable to system (computer) control.

Flexibility is a desirable attribute of sequence control, provided the designer heeds several cautions: (1) Errors in sequence control should be expected, just like data entry errors. Therefore, error correction mechanisms must be included for both system-detected and user-detected errors. (2) Total flexibility may not be appropriate for all types of users. Maximum flexibility may be appropriate for experienced or professional users, whereas it may confuse novice or infrequent users. Failure to provide appropriate levels of flexibility to match the various levels of users will prove frustrating to the users for whom the system is not designed. This issue can be addressed, partly, in the selection of the type of dialogue to be employed. Options, such as multiple dialogue types or user selectable amounts of user control, should be considered. These issues are considered in the guidelines provided in Table 22.

APPLICATIONS

Interactive dialogue design; data base system design.

CONSTRAINTS

- The guidelines provided for sequence control may not have been empirically validated.

TABLE 22. SELECTED GUIDELINES FOR DESIGN OF SEQUENCE CONTROL

USER CONSIDERATIONS

Minimize User Actions
- Simplify control actions to maximum extent
- Design for minimum number of required control entries consistent with user abilities

Match Ease of Sequence Control with Desired Ends
- Frequent or urgent actions - easy and quick control
- Potentially destructive actions - distinctive actions under explicit user control

Match Control to Level(s) of User Skill
- May require mixed dialogue or entry stacking option

Require Explicit User Actions
- Computer should not interrupt user entries until conclusion
- Routine actions can benefit from computer control

Permit Initiative and Control by User
- Anticipate all possible user actions and consequences
- Provide appropriate options for each potential user action
- Avoid "dead-ends" in dialogues
- Allow user to interrupt, defer, or abort transaction sequences

User Pace Sequence Control
- Design for user's needs, attention span and time available

Prevent Interference Between Simultaneous Users

LOGIC CONSIDERATIONS

Design Consistent Control Actions Throughout a System

Control Actions Should be Independent of Prior Actions

Base Linked Transaction Sequences on User Task Analysis
- "Logical unit" of user, not logical unit of computer system, should determine transaction sequence

Establish Consistent Terminology for Instructional Materials, On-Line Messages and Command Terms

Offer Active Options Only

TABLE 22. SELECTED GUIDELINES FOR DESIGN OF SEQUENCE CONTROL (Cont.)

LANGUAGE CONSIDERATIONS

Base Choice of Dialogue and Design of Sequence Control on User and Task Characteristics

- Question-and-answer dialogue: for routine data entry tasks, where data items are known and their ordering can be constrained, where the user will have little or no training, and where computer response is expected to be moderately fast
- Form-filling dialogue: when some flexibility in data entry is needed, such as the inclusion of optional as well as required items, where users will have moderate training, and/or where computer response may be slow
- Menu selection: tasks such as scheduling and monitoring that involve little entry of arbitrary data, where users may have relatively little training, and where computer response is expected to be fast
- Function keys: tasks requiring only a limited number of control entries, or in conjunction with other dialogue types as a ready means of accomplishing critical entries that must be made quickly without syntax error
- Command language: tasks involving a wide range of user control entries, where users may be highly trained in the interests of achieving efficient performance, and where computer response is expected to be relatively fast
- Query language: specialized sub-category of general command language for tasks emphasizing unpredictable information retrieval (as in many analysis and planning tasks), with moderately trained users and fast computer response
- Graphic interaction: supplement to other forms of human-machine dialogue where special task requirements exist; effective implementation of graphic capabilities will require very fast computer response

INPUT/OUTPUT CONSIDERATIONS

Computer Response Time Should Match Transaction

- Faster response for those perceived by user to be simpler

Entries Should Not Be Paced by Computer Response Delays

- When delays are unavoidable, keyboard should automatically lock
- Following lockout, computer readiness should be signaled to user
- User should be provided with means of aborting transaction during lockout

Provide Unambiguous Feedback for Control Entries

- Signal completion of processing
- Unambiguous feedback can be immediate execution, change in state or acceptance/ rejection message

Design Sequence Control Features to be Distinctive in Position or Format

KEY REFERENCES

1. Smith, S. L. (1980). Requirements definition and design guidelines for the man-machine interface in C3 system acquisition (ESD-TR-80-122). Bedford, MA: MITRE Crop. (NITS AD A087 258).

*2. Smith, S. L., & Aucella, A. F. (1983). Design guidelines for the user interface to computer-based information systems (ESD-TR-83-122). Bedford, MA: MITRE Corp.

CROSS REFERENCES

1. Steps in person-computer dialogue design; 3. Comparison of approaches to person-computer dialogue

*Principal reference

20. ERROR RECOVERY IN PERSON-COMPUTER DIALOGUE

KEY TERMS

ERRORS; OMISSIONS; FEEDBACK; DIRECTIONAL GUIDANCE; PROMPTING; ERROR CORRECTION

GENERAL DESCRIPTION

Although 80% of all keying errors are detected consciously, person-computer dialogue design should aid the user in correcting and recovering from system-detected errors. Recovery techniques should consider feedback, directional guidance, temporal and spatial proximity, opportunity for immediate correction, and availability of relevant documentation. The failure to consider any of these has varying negative impact on the probability of correct and rapid recovery from an error.

Table 23 incorporates these principles into guidelines for error detection, error message design, and error correction. When little attention is given to these considerations, system performance degrades due to excessive user time spent searching for, and correcting, errors. Error recovery mechanisms should be designed to maximize the educational/training aspect, with the intention of reducing future reoccurrences. The level of effort required to correct errors should be minimized to permit maximum user concentration on the problem-solving aspects of error recovery.

APPLICATIONS

Dialogue design; design of data entry systems; design of data base query systems.

CONSTRAINTS

- The specific procedures on how to handle user input errors and what to communicate for effective error recovery have not been systematically researched.

KEY REFERENCES

*1. Engel, S. E., & Granda, R. E. (1975). Guidelines for man/display interfaces (00.2720). Poughkeepsie, NY: IBM.

2. Hendricks, D., Kilduff, P., Brooks, P. Marshak, R., & Doyle, B. (1982). Human engineering guidelines for management information systems. Alexandria, VA: U.S. Army Materiel Development and Readiness Command.

CROSS REFERENCES

10. Interface design principles derived from human error analyses; 17. Data entry displays; 19. Sequence control in person-computer dialogue

---

*Principal reference

TABLE 23. GUIDELINES FOR ERROR DETECTION, MESSAGE DESIGN AND CORRECTION

ERROR DETECTION

- Users should be able to stop and return to previous levels of a multi-level control process at any point in a sequence as a result of user-detected error.
- Rejected inputs should result in an error message with highlighting of the erroneous portion.
- Batched or stacked strings of entries should be processed (executed) to the point of error and then an error message should be sent.
- Error messages should be provided as soon as possible after detection by the system.
- For multiple errors, the number of errors detected and their locations should be displayed until they are corrected.
- Errors made while correcting errors should result in new error messages.
- User input errors should be minimized through internal software validation of entries, such as detection of numerics entered in alpha fields.

ERROR MESSAGE DESIGN

- System-detected errors should result in messages providing as much diagnostic information and remedial action as can be inferred reliably from the error condition.
- Error messages should reflect the user's point of view of what is needed for recovery.
- All error message should indicate:
  a. location of error
  b. nature of error
  c. one or more ways to recover or where to find out how to recover.
- Error messages should appear as close as possible to the erroneous entry.
- Error message should be understandable and non-threatening to user (avoid computer-jargon, humorous or condemning messages).
- User should be able to select the amount of detail contained in error messages; two levels of messages will be sufficient for most cases.

ERROR CORRECTION

- An easy means of correcting erroneous entries should be provided.
- When an error has occurred, the system should allow immediate correction.
- A user should not have to reenter an entire line because of an omission or misspelling of one word.
- Lines of input should be alterable during, as well as after, entry.
- Users should be able to stop and return, at any point, to previous levels of multi-level control processes.

21. DESIGN AND CONTROL OF CURSORS

KEY TERMS

POSITION INDICATOR; POSITION DESIGNATION; DATA ENTRY

GENERAL DESCRIPTION

Cursors provide position designation for information to be entered or selected by the user. Table 24 provides design considerations for five types of tasks in person-computer dialogue. In general, movable cursors should be designed to:

- Be located easily at random positions; be tracked easily while moving;
- Not interfere with the symbol/position being marked;
- Not distract or impair searches for other displayed information;
- Have a consistent starting point within frame as well as between frames;
- Remain stable (drift-proof) until positioned or repositioned;
- Be box or block-type with optional 3 kHz blinking.

APPLICATIONS

Position designation for user inputs and information location or selection markers.

CONSTRAINTS

- Design of cursors and control devices is a function of task being performed by the user.
- Variable character size on display requires variable step size of incremental stepping cursor.
- Incremental stepping cursor should have consistent step size in all directions of movement.

KEY REFERENCES

*1. Hendricks, D., Kilduff, P., Brooks, P., Marshak, R., & Doyle, B. (1982). Human engineering guidelines for management information systems. Alexandria, VA: U.S. Army Materiel Development and Readiness Command.

*2. Smith, S. L., & Aucella, A. F. (1983). Design guidelines for the user interface to computer-based information sytems (ESD-TR-83-122). Bedford, MA: The MITRE Corp.

CROSS REFERENCES

31. Prompting in person-computer dialogue

---

*Principal reference

TABLE 24. SELECTED DESIGN CONSIDERATIONS FOR POSITION DESIGNATION CURSORS

TASK TYPE (as sole or primary dialogue mechanism	DESIGN CONSIDERATIONS	PRINCIPAL CONTROL DEVICE
Continuous Positioning		
(a) Rough	(a) At least 20-30 cm displacement in 0.5 sec	Continuously operable controls: • Thumbwheel • Joystick • Mouse
(b) Fine	(b) Options include: • Point designation (like cross-hairs or gunsight) feature is desirable • Incremental stepping • Large control/display ratios • Selectable vernier modes	
Sequential Positioning	User action for cursor movement should be minimized	Programmable tab keys
Pointing and Item Selection	Target area should be as large as consistently possible: Label area plus half character distance around label	Direct pointing types • Lightpen • Touch screen Highlighting selected item
Keyed Data Entry	Minimize cursor positioning movements and search time	Integral to keyboard • Function keys • Joystick Automatic positioning
More Than One Task Using Multiple Cursors	Cursors should be visually distinctive Minimize use of multiple cursors to reduce user confusion Single device control - • Indicate to user which cursor is being controlled Multiple device control - • Controls should be compatible in operation	Select by above listed task types

22. ON-LINE DOCUMENTATION

KEY TERMS

HELP; ERROR MESSAGES; USER GROUPS

GENERAL DESCRIPTION

Off-line documentation, as well as on-line documentation and help sequences, when designed according to a single "style," typically do not provide adequate levels of information for both novice and experienced users. Inclusion of on-line message layering or selectable message levels can be utilized successfully to meet various needs. Table 25 presents general guidelines for design of documentation and help sequences.

Table 26 describes two different approaches to designing on-line help for two types of interactive systems: programmers and non-programmers. These approaches were empirically compared (Ref. 3) and the results support a benefit associated with the multiple message type approach. The study showed that seemingly superficial differences in message style have a significant affect on novice user performance.

APPLICATIONS

Documentation design; on-line help facility design.

METHODOLOGY

Stimulus and Viewing Conditions

- On-line help messages (two versions as described in Table 26) presented on a DEC VT100 terminal under DEC VAX/VMS operating system version 2.3.

Procedure and Experimental Design

- Two-group, between subject experiment.
- Typical fully-automated office task involving computer file manipulation: creation and distribution of reports from pre-written material.
- Independent variable: Style of help and error messages.
- Dependent variables: Objective-number of commands and time consumed for task completion, errors, and accessing of system information; subjective-level of user satisfaction.
- Thirty-two paid observers (Os); computer-novices

EXPERIMENTAL RESULTS

- Ninety-three percent (93%) of subjects using "non-programmer" style completed the task, whereas 20% in "programmer" style completed the task; mean task completion time was 52 min in "non-programmer" versus 84 min in "programmer" style.

TABLE 25. SELECTED GUIDELINES FOR DESIGN OF ON-LINE AND OFF-LINE DOCUMENTATION (Source: Williges & Williges, 1984)

HELP AND DOCUMENTATION

On-line documentation, off-line documentation and help sequences should use consistent terminology.

Off-Line Documentation

All error messages should be listed and explained in the off-line system documentation.

Every nonmenu frame should contain a reference to a specific section of off-line documentation to provide a ready source of explanation.

On-Line Documentation

After accessing help, the user should be provided with an easy way to return to the main dialogue.

On-line access to help facilities should be provided for each command.

All error messages should be listed and explained in the on-line help sequences.

A dictionary of abbreviations and codes used should be available on-line.

On-line access to a list of system capabilities and subsystems should be provided. By showing the system components, options, and structure, the on-line reference capability permits the user to understand the use of the system effectively.

When possible, natural language, rather than an hierarchic menu, should be used to invoke on-line documentation.

If more details are needed, the user can ask for a continuation. Successive levels of the HELP request can go into greater detail.

TABLE 26. DIFFERENCES BETWEEN THE ON-LINE HELP MODIFIED FOR NON-PROGRAMMERS AND THE SYSTEM FOR PROGRAMMERS (Source: Magers, 1983)

PROGRAMMER'S SYSTEM	NON-PROGRAMMER'S SYSTEM
HELP command only	HELP command and HELP key
Keyword indexed Help	Context-sensitive Help
Rigid rules for forming correct HELP commands	More lenient rules for forming correct HELP commands
Mostly reference Help	Tutorial Help and reference Help
Uses computer jargon	Reasonably jargon-free or jargon explained
Uses mathematical notation	Uses examples
Error messages	Suggested correction messages
No feedback when command correct	Positive feedback messages confirm correct commands
Unlimited access to all computer commands	Commands available to novices limited
Precise command names required	On-line dictionary of command synonyms
Lengthy Help "scrolls" on screen	Help in short, two-thirds of screen-sized frames
Computer-oriented Help	User-task-oriented Help

- Performance under "non-programmer" style was significantly better than in "programmer" style: higher task score, more commands per min, fewer references to off-line documentation and fewer questions asked.
- Total number of commands generated using "non-programmer" style was not greater than in "programmer" style, but they were produced nearly twice as rapidly (1.95 per min versus .99 per min).
- Fewer erroneous commands were generated using "non-programmer" style than using "programmer" style. Less total time (7.4 versus 33.4 min) was spent generating erroneous commands using "non-programmer" versus "programmer" style.
- Greater usage of help commands was measured in "non-programmer" style than in "programmer" style.
- Subjective evaluation displayed significant preference for "non-programmer" style over "programmer" style. Preference focused on greater ease-of-use and ease-of-learning, less frustrating, less complex, and less confusing, greater flexibility and personal control, more friendly, more on-line help and better error messages.

CONSTRAINTS

- Experienced users were not compared; novice users only.
- Guidelines presented in Table 25 may not be empirically based.

KEY REFERENCES

1. Brown, C. M., Burkleo, H. V., Mangelsdorf, J. E., Olsen, R. A., & Williams, A. R., Jr. (1981). Human factors engineering criteria for information processing systems. Sunnyvale, CA: Lockheed.
2. Galitz, W. O. (1981). Handbook of screen format design. Wellesley, MA: Q.E.D. Information Sciences.

*3. Magers, C. S. (1983, December 12-15). An experimental evaluation of on-line help for non-programmers. In Janda, A. (Ed.) Proceedings of CHI-83 Human Factors in Computing Systems (pp. 1-10). New York: Association for Computing Machinery.

4. Miller, L. A., & Thomas, J. C., Jr. (1976). Behavioral issues in the use of interactive systems (RC 6326). Yorktown Heights, NY: IBM.
5. Parrish, R. N., Gates, J. L., Munger, S. J., & Sidorsky, R. C. (1981). Development of design guidelines and criteria for user/operator transactions with battlefield automated systems. Volume IV: Provisional guidelines and criteria for the design of user/operator transactions. Alexandria, VA: U.S. Army Research Institute.
6. Pew, R. W., & Rollins, A. M. (1975). Dialog specification procedures (3129). Cambridge, MA: Bolt, Beranek and Newman, Inc.

*7. Williges, B. H., & Williges, R. C. (1984). Dialogue design considerations for interactive computer systems. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: Human Factors Society.

*Principal reference

CROSS REFERENCES

12. Designing for the casual or infrequent computer user; 20. Error recovery in person-computer dialogue; 31. Prompting in person-computer dialogue

23. AIDS TO PERSON-COMPUTER PROBLEM-SOLVING

KEY TERMS

PROBLEM-SOLVING BEHAVIOR; PROBLEM RECOGNITION; PROBLEM DEFINITION; GOAL DEFINITION; STRATEGY SELECTION; ALTERNATIVE GENERATION; ALTERNATIVE EVALUATION; ALTERNATIVE SELECTION AND EXECUTION; DECISION-MAKING

GENERAL DESCRIPTION

Problem-solving with abstraction results in the reformulation of problems into more general, higher-level terms. The aiding mechanisms focus on problem definition and selection of strategy. When no abstraction is used, the solutions are directly related to the problem-solving behavior; therefore, the focus is on alternative generation, evaluation, and execution.

Search behavior is problem solution generation by application of inference rules and heuristics to a set of potential solutions. No-search problem-solving involves identification and retrieval of solutions to similar problems which were previously solved.

Data-driven problem-solving relies on problem recognition and alternative evaluation based on domain-dependent aspects of the problem. Conceptually-driven problem-solving is dependent upon the problem solver's prior experience, focusing on problem recognition and alternative evaluation.

Table 27 relates these problem-solving behaviors to mechanisms for the aiding of decision-making.

APPLICATION

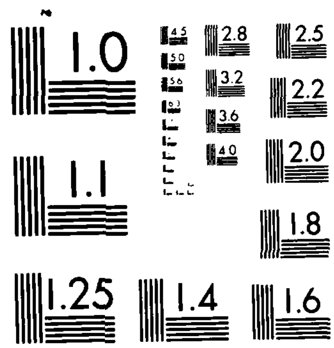
Selection of appropriate aiding mechanisms for person-computer problem-solving.

CONSTRAINTS

- Aiding mechanisms are limited to generation tasks as opposed to recognition tasks.
- Specific task and experience of user affect the problem-solving behavior that is used.
- Requirements analysis may identify more than one type of behavior exhibited.
- Knowledge of problem-solving aids is known and is presented at an abstract level, rather than as specific guidelines.

AD-A163 074 PERSON COMPUTER DIALOGUE: A HUMAN ENGINEERING DATA BASE 2/2
SUPPLEMENT(U) ESSEX CORP WESTLAKE VILLAGE CA HUMAN
FACTORS AND TRAINING SYS B E SHAW ET AL JAN 85
UNCLASSIFIED AFAMRL-TR-85-013 F33615-82-C-0513 F/G 9/2 NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 27. RELATIONSHIP OF AIDING MECHANISMS TO TYPES OF PROBLEM-SOLVING BEHAVIOR (Source: Ramsey & Atwood, 1979)

AIDING MECHANISM	BEHAVIOR TYPE					
	Abstraction	No Abstraction	Search	No Search	Data-Driven	Conceptually-Driven
Alternative evaluation		X	X		X	
Alternative generation		X	X			
Automatic action execution				X		
Automatic takeover*						
Better weighting of unreliable data					X	
Change of problem representation	X					X
Decision consistency improvement					X	
Decision strategy improvement	X					X
Decomposition and recombination	X					
Disruption of psychological set*						
Extended memory		X	X	X		X
Lockout*						
Rapid trial-and-error		X	X			
Strategy capture					X	

*Relationship with behavior type not identified in original source.

KEY REFERENCES

1. Ramsey, H. R., & Atwood, M. E. (1979). Human factors in computer systems: A review of the literature (SAI-79-111-DEN). Englewood, CO: Science Applications, Inc. (NTIS No. AD A075 679)

CROSS REFERENCES

None.

24. VOICE VERSUS WRITTEN COMMUNICATIONS FOR PROBLEM SOLVING

KEY TERMS

COMMUNICATIONS MODES; VOICE INPUT; KEYBOARD INPUT

GENERAL DESCRIPTION

A series of studies was performed to derive dialogue principles in person-person communication as a basis for establishing principles for person-computer dialogue. When two people must communicate to solve a problem, solutions are achieved more quickly with voice communications than by handwriting or typewriting. However, these communications have almost no syntactical structure, and subjects using the voice modes generated eight times as many words as subjects using the writing modes.

APPLICATIONS

Designers of person-computer dialogues, particularly those responsible for constraining the behavior of the human through software syntax, should be aware of the communications tendencies of humans when a syntax is not imposed. Designers or advocates of the "natural language interface" concept should be aware of the "unruly" verbal tendencies of human problem solvers.

METHODOLOGY

Materials

A room separated by a removable cloth panel contained a teletype console and a video monitor.

Procedure

Pairs of subjects solved problems by communicating in one of three conditions: (a) face-to-face (communication rich), (b) voice (no-vision), (c) typewriting. Subjects in the typewriting condition were classified as either experienced or inexperienced typists. The subjects were college and high school students who solved problems, such as equipment assembly, in which one subject had the assembly directions and the other had the parts. All communications were observed and recorded.

The independent variables were five conditions of communication: (1) face-to-face, (2) voice, (3) handwriting, (4) typewriter (experienced), and (5) typewriter (inexperienced). The dependent variables were: (1) time to solve the problem, and (2) measures of communications content and structure. Post-analysis and intercorrelations yielded nine useful measures: (1) number of messages generated by each subject, (2) number of sentences generated by each subject, (3) number of words per message, (4) number of words per sentence, (5) percentage of sentences that were questions, (6) number of words used by a subject, (7) total number of different words used by a subject, (8) ratio of different words to total words, and (9) communication rate (number of words communicated per min during communications).

EXPERIMENTAL RESULTS

Time for solving problems is shown in Table 28 for the five communications types. The voice modes were associated with faster problem solution times than handwriting or typing. Despite the arguments for nonverbal communication, the time taken to solve problems by voice alone was only slightly greater than with face-to-face communication (which allowed pointing and other non-verbal cues).

TABLE 28. PROBLEM SOLVING TIME FOR SEVEN MEASURES OF COMMUNICATIONS (Source: Chapanis, 1975)

	COMMUNI-CATION RICH	VOICE	HAND-WRITING	TYPEWRITING	
				EXPERIENCED TYPISTS	INEXPERIENCED TYPISTS
Solution Time in Minutes	29.0	33.0	53.3	66.2	69.0
Number of Messages	230.4	163.8	15.9	27.2	31.5
Number of Sentences	372.6	275.9	24.9	45.8	44.1
Total Number of Words	1,563.8	1,374.8	224.8	322.9	257.4
Total Number of Different Words	397.5	305.9	118.5	150.5	133.4
Ratio of Difficult Words to Total Words	.3	.3	.6	.5	.6
Number of Words Per Minute	190.3	171.2	17.3	18.1	10.2

Figure 9 enumerates results for seven measures of communications according to the five experimental conditions. The results indicate that problem solving by voice takes the least time, but is wordier than other modes of communication. In general, all of the communications modes studied involved rather "unruly" adherence to grammatical, syntactical and semantic rules.

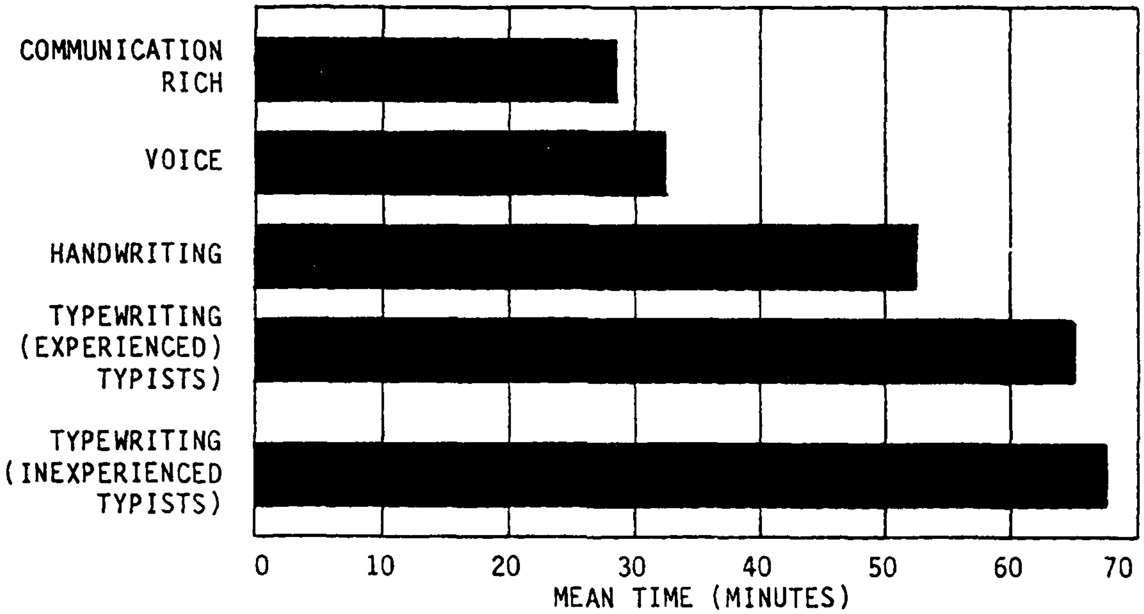


Figure 9. Problem-solving time for five communications types. (Source: Chapanis, 1975)

CONSTRAINTS

- These data bear on human-computer dialogue only indirectly and by inference.
- The studies used dyads only.
- The data do not indicate the capability and limitations of humans to comply with syntactical structure, when required.
- Individual differences in imposing syntax on communications are not described.
- The tendency to avoid language structure in communications found in these studies is not specific enough to formulate predictions about the frequency and type of non-compliance to be expected when a rigid syntax is imposed, as in person-computer dialogue with early 1980s systems.

KEY REFERENCES

1. Chapanis, A. (1975). Interactive human communication. Scientific American, 232, 36-42.

CROSS REFERENCES

1. Steps in person-computer dialogue design

25. PRESENTING NUMERIC DATA IN PERSON-COMPUTER DIALOGUE

KEY TERMS

NUMERIC CODES; NUMBER PRESENTATION; DATA PRESENTATION

GENERAL DESCRIPTION

Well-designed formatting of numerical information displays can facilitate the comprehension and comparison of the data by the user. Table 29 presents guidelines for presentation of numeric data.

APPLICATIONS

Display of numeric information such as part numbers, telephone numbers, scores on a series of tests, and storage dumps; data entry.

CONSTRAINTS

- Most of these guidelines are not based on experimental studies; others are loosely based on empirical findings.

KEY REFERENCES

1. Brown, C. M., Burkleo, H. V., Mangelsdorf, J. E., Olsen, R. A., & Williams, A. R., Jr. (1981). Human factors engineering criteria for information processing systems. Sunnyvale, CA: Lockheed.
2. Engel, S. E., & Granda, R. E. (1975). Guidelines for man/display interfaces (TR 00.2720). Poughkeepsie, NY: IBM.
3. Galitz, W. O. (1981). Handbook of screen format design. Wellesley, MA: Q.E.D. Information Sciences.
4. Martin, J. (1973). Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.
5. Parrish, R. N., Gates, J. L., Munger, S. J., & Sidorsky, R. C. (1981). Development of design guidelines and criteria for user/operator transactions with battlefield automated systems. Vol. IV: Provisional guidelines and criteria for the design of user/operator transactions. Alexandria, VA: U.S. Army Research Institute.
6. Pew, R. W., & Rollins, A. M. (1975). Dialog specification procedures (rev. ed.) (Report No. 3129). Cambridge, MA: Bolt, Beranek and Newman, Inc.
7. Smith, S. L. (1981). Man-machine interface (MMI) requirements definition and design guidelines: A progress report (ESD-TR-81-113). Bedford, MA: The MITRE Corp.

*8. Williges, B. H., & Williges, R. H. (1984). Dialogue design considerations for interactive systems. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: Human Factors Society.

---

*Principal reference

TABLE 29. GUIDELINES FOR DISPLAY OF NUMERIC DATA

Long Numeric Sequences

- Should be displayed in groups of three to four (where no natural split or no pre-defined break occurs), as in social security numbers with a blank character between them. (Refs. 1 & 2)

Not:	But:
106619751492	1066 1914
121519411861	1215 1918
191418651945	1492 1941
1917	1861 1945
	1865 1975

Numeric Fields

- Lists of numbers without decimals should be right-justified. (Refs. 1, 4, & 5)
- Lists of numbers with decimals should use decimal alignment. (Ref. 1)
- Do not assume that the user can identify individual fields because of past familiarity; context plays a significant role. Therefore, identify or label the field. (Ref. 2)
- Present data fields in some recognizable order if possible, for ease of scanning and identification. For example, put historical dates in chronological order. (Ref. 2)
- Numeric codes should be restricted to six or fewer digits. (Ref. 3)
- Leading zeros should not be required except where needed for clarity. (Refs. 1, 2, 3, & 7)

Standardized Formats

- Identical data should be presented to the user in a standard and consistent manner, despite its module of origin. (Ref. 2)
- Do not change current accepted formats. Change only when task or activity must be clearly differentiated from other similar tasks. (Ref. 2)
- Suggested standardization of basic data fields for American civilian users: (Ref. 2)
  - Telephone: 914-444-0111
  - Time : HH:MM:SS, HH:MM, MM:SS(.S)
  - Date : MM/DD/YY

CROSS REFERENCES

26. Presenting text data in person-computer dialogue; 27. Presenting tabular data in person-computer dialogue

26. PRESENTING TEXT DATA IN PERSON-COMPUTER DIALOGUE

KEY TERMS

TEXTUAL DATA; ALPHANUMERIC; TEXT DISPLAY; INTERACTIVE DIALOGUE

GENERAL DESCRIPTION

A good format for text-based information can facilitate comprehension and comparison of the data by the user. Table 30 presents guidelines for presentation of text data.

TABLE 30. CONSIDERATIONS FOR DISPLAY OF TEXT DATA

Display of Text Data

- Small screen - no more than 50-55 characters per line of data. (Refs. 2 & 3)
- Large screen - two or more columns of 30-35 characters per line. (Refs. 2 & 3)
- Mixture of upper and lower case preferable. (Refs. 1, 2, & 3)
- Left justify text. (Refs. 1, 2, 4, & 5)
- Separate paragraph by at least one blank line. (Ref. 2)
- For reading ease, field width should be 40 characters or less. (Ref. 3)

Display of Alphanumeric Data

- Each character type should be grouped together and not interspersed. (Refs. 2 & 6)
- Strings of five or more alphanumerics should be grouped into three or four characters where no natural split or predefined break occurs or should be grouped at natural breaks. (Ref. 4)

Multi-Column Displays

- Right justified text - separate columns by at least eight spaces. (Refs. 2 & 3)
- Left justified text - separate columns by three to four spaces. (Refs. 2 & 3)

Grammatical Style

- Statements should be made in the affirmative. (Refs. 1 & 3)
- Active voice should be used, whenever possible. Active voice is generally easier to understand than passive voice. (Ref. 1)
- If a sentence describes a sequence of events, the word order in the sentence should correspond to the temporal sequence of events. (Refs. 1 & 3)
- Short simple sentences should be used. (Refs. 1 & 3)
- Sentences should begin with the main topic. (Refs. 1 & 3)

APPLICATIONS

Computer-assisted instruction; word processing systems; text-based person-computer dialogues; viewdata systems.

CONSTRAINTS

- Most of these guidelines are not based on experimental studies; others are loosely based on empirical findings.

KEY REFERENCES

1. Brown, C. M., Burkleo, H. V., Mangelsdorf, J. E., Olsen, R. A., & Williams, A. R., Jr. (1981). Human factors engineering criteria for information processing systems. Sunnyvale, CA: Lockheed.
2. Engel, S. E., & Granda, R. E. (1975). Guidelines for man/display interfaces (TR 00.2720). Poughkeepsie, NY: IBM.
3. Galitz, W. O. (1981). Handbook of screen format design. Wellesley, MA: Q.E.D. Information Sciences.
4. Martin, J. (1973). Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.
5. Parrish, R. N., Gates, J. L., Munger, S. J., & Sidorsky, R. C. (1981). Development of design guidelines and criteria for user/operator transactions with battlefield automated systems. Vol. IV: Provisional guidelines and criteria for the design of user/operator transactions. Alexandria, VA: U.S. Army Research Institute.

*6. Williges, B. H., & Williges, R. C. (1984). Design considerations for interactive computer systems. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: Human Factors Society.

CROSS REFERENCES

25. Presenting numeric data in person-computer dialogue; 27. Presenting tabular data in person-computer dialogue; 30. Abbreviations and acronyms

*Principal reference

27. PRESENTING TABULAR DATA IN PERSON-COMPUTER DIALOGUE

KEY TERMS

DATA TABLES; ITEM LISTS

GENERAL DESCRIPTION

Display of data in tabular format facilitates comprehension and comparison of the data. Table 31 presents guidelines for formatting data into tables.

TABLE 31. GUIDELINES FOR DISPLAY OF TABULAR DATA

Formatting Data into Lists

- Each item should start on a new line. (Ref. 1)
- Items should be arranged in recognizable and useful order (Ref. 1), such as:

  Chronological
  Alphabetical
  Sequential
  Functional
  Frequency of use
  Importance.

- Items not used for selection may be enumerated with "bullets." (Ref. 1)
- Block tabular data displays, whenever possible, to reduce user search time for data. (Ref. 2)
- When a list extends beyond the amount that can be shown on one display page, a short message should be provided to indicate that the list is not complete. (Ref.1)

Justification of Lists

- For rapid scanning, lists should be left-justified and aligned vertically. Subclasses can be indented. (Ref. 3)
- The computer should handle the left- or right-justification of data entries and the justification of numeric lists on the decimal point. (Ref. 4)

APPLICATIONS

Data to be scanned and compared by the user.

CONSTRAINTS

- Most of these guidelines are not based on experimental studies; others are loosely based on empirical findings.
- Graphic or tabular displays should offer, as an option, the ability to look at raw data (Ref. 3).

KEY REFERENCES

1. Brown, C. M., Burkleo, N. V., Mangelsdorf, J. E., Olsen, R. A., & Williams, A. R., Jr. (1981). Human factors engineering criteria for information processing systems. Sunnyvale, CA: Lockheed.
2. Cropper, A. G., & Evans, S. J. W. (1968). Ergonomics and computer display design. The Computer Bulletin, 12, 94-98.
3. Engel, S. E., & Granda, R. E. (1975, December). Guidelines for man/display interfaces (TR 00.2720). Poughkeepsie, NY: IBM.
4. Smith, S. L. (1981, February). Man-machine interface (MMI) requirements definition and design guidelines: A progress report (ESD-TR-81-113). Bedford, MA: MITRE Corp.

*5. Williges, B. H., & Williges, R. C. (1984). Dialogue design considerations for interactive computer systems. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: Human Factors Society.

CROSS REFERENCES

25. Presenting numeric data in person-computer dialogue; 26. Presenting text data in person-computer dialogue

*Principal reference

28. GRAPHICS IN PERSON-COMPUTER DIALOGUE

KEY TERMS

COMPUTER GRAPHICS; DISPLAYS; DATA GRAPHS; ANIMATION; SPATIALLY-ORIENTED DATA

GENERAL DESCRIPTION

Graphic presentations greatly aid interpretation and comparison of numeric or spatially-oriented data. In Table 32, guidelines are given for design of graphic displays.

APPLICATIONS

Spatial visualization problems; problems with multiple interacting dimensions; display of numeric data; graphical dialogues.

CONSTRAINTS

- Although data in graphic form is more easily inspected and compared, raw data should be provided as an option to the user (Ref. 2).
- Most of these guidelines are not based on experimental studies; others are loosely based on empirical findings.

KEY REFERENCES

1. Barmack, J. E., & Sinaiko, H. W. (1966). Human factors problems in computer-generated graphic displays (Study S-234). Washington, DC: Institute for Defense Analyses.
2. Engel, S. E., & Granda, R. E. (1975). Guidelines for man/display interfaces (TR 00.2720). Poughkeepsie, NY: IBM.
3. Foley, J. D., Wallace, V. L., & Chan, P. (1981, January). The human factors of graphic interaction: Tasks and techniques (GWU-IIST-81-3). Washington, DC: George Washington University.
4. Martin, J. (1973). Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.
5. Newman, W. M., & Sproull, R. F. (1979). Principles of interactive computer graphics. New York, NY: McGraw-Hill.
6. Schutz, H. G. (1961). An evaluation of methods for presentation of graphic multiple trends: Experiment III. Human Factors, 3, 108-119.

*7. Williges, B. H., & Williges, R. C. (1984). Dialogue design considerations for interactive computer systems. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: Human Factors Society.

*Principal reference

TABLE 32. DESIGN GUIDELINES FOR GRAPHIC PRESENTATIONS

Labels

- Describe what is being displayed - not the name of the display. (Ref. 1)
- Always label axes. (Ref. 4)

Axis Subdivision and Scales

- Letter size used for labeling scales should be independent of scales. If display is contracted to a smaller size, labels must remain large enough to be readable. (Ref. 1)
- Units of 1, 2, 5, or 10 should be used to subdivide scales - not 3, 7, or numbers arbitrarily obtained through division. (Ref. 1)
- Limit number of graduation marks to 9. (Ref. 1)
- Number scales starting at zero. (Ref. 1)
- Increase magnitude clockwise (left —— right; bottom —— top)

Displayed Values

- Maximize contrast between values and scale markings. (Ref. 1)
- Multiple trend lines on single graph facilitates comparison. (Ref. 6)

Symbols

- Consider the graphics conventions familiar to user. (Ref. 5)

Display Complexity

- Avoid unnecessary ornamentation, unwanted graphic patterns and illusions, and alignment flaws. (Ref. 5)

Display Rotation

- Center of rotation should be center of object.
- Labels should not rotate with object if they will not remain horizontal.

CROSS REFERENCES

17. Data entry displays; 32. Screen layout and structuring of person-computer dialogue displays

29. INFORMATION CODING IN PERSON-COMPUTER DIALOGUE

KEY TERMS

HIGHLIGHTING; COLOR CODING; SHAPE CODING; BLINKING CODING; BRIGHTNESS CODING; ALPHANUMERIC CODING

GENERAL DESCRIPTION

Coding of displayed information can increase the efficacy of interpretation by emphasizing relationships between displayed data elements and by reducing a user's search-and-identification time. Table 33 describes five principal coding techniques and discusses critical factors for selection of optimal codes. Techniques are presented in approximate order of effectiveness, with color coding being preferred.

APPLICATIONS

Qualitative information displays; quantitative information displays.

CONSTRAINTS

- Codes must be meaningful and consistent with user expectations and population stereotypes.
- Coding for attention-getting should not be overused, or effectiveness will diminish.
- Coding which will reduce legibility or increase transmission time should not be used.
- Color coding can be seriously degraded if ambient illumination is not controlled.
- Coding, typically, should be redundant.

KEY REFERENCES

1. Brown, C. M., Burkleo, H. V., Mangelsdorf, J. E., Olsen, R. A., & Williams, A. R. Jr. (1981, June). Human factors engineering criteria for information processing systems. Sunnyvale, CA: Lockheed.

*2. Engel, S. E., & Granda, R. E. (1975). Guidelines for man/display interfaces (00.2720). Poughkeepsie, NY: IBM.

3. Galitz, W. O. (1981). Handbook of screen format design. Wellesley, MA: Q.E.D. Information Sciences.

4. Hutchinson, R. D. (1981). New horizons for human factors in design. New York, NY: McGraw-Hill.

5. Miller, L. A., & Thomas, J. C. Jr. (1976, December). Behavioral issues in the use of interactive systems (RC6326). Yorktown Heights, NY: IBM.

*Principal reference

TABLE 33. GENERAL GUIDELINES FOR SELECTION OF INFORMATION CODING TECHNIQUES

CODE TYPE	RECOMMENDED APPLICATIONS	LIMITATIONS	DESIGN GUIDELINES
Color	Search tasks Highlighting of related data in a display Locating: o Headings o Out-of tolerance data o Newly entered data o Important data fields o Urgent data	Color blindness (especially red) in 8% of males Three to ten hue color limit Maximum of eleven codes should be used Registration of overlayed colors Warm colors (red, yellow) generally appear larger than cool colors (blue, green) in graphics Color codes may not transfer required information to monochromatic displays	Consider established color meanings in code selection, example: o Red = Danger o Yellow = Caution o Green = Normal Color codes should be unique and defined on display Recommended colors (Ref. 1): o Green - principal color o White - headings o Pink - alarms o Yellow - related data o Turquoise/Cyan - user input
Shape o Geometric o Pictographs	Search and identification tasks	Fifteen shape maximum	Use of fewer shapes increases accuracy of identification
Blinking	Alarms Target detection tasks in high density displays	Not for use with long-phosphor displays Maximum of four different blink rates	User-optional is preferable Blinking should cease after user response Blink rate should match user's reading scan rate Binary coding is preferred Recommended blink rates: o 2-3 Hz with 80 ms minimum (Ref. 2) o 3-7 Hz (Ref. 7)
Brightness	User selected display items	10% or less of display should be highlighted at once No more than three levels of brightness	Provide maximum contrast between items highlighted and other items
Alphanumeric	Absolute identifications	Confusion of symbols	Avoid use of frequently confused character pairs, including: o 5-S o 0-Ø o I-1 o Z-2

6. Parrish, R. N., Gates, J. L., Munger, S. J., & Sidorsky, R. C. (1981). Development of design guidelines and criteria for user/operator transactions with battlefield automated systems. Vol. IV: Provisional guidelines and criteria for the design of user/operator transactions. Alexandria, VA: U.S. Army Research Institute.

*7. Ramsey, H. R., & Atwood, M. E. (1979). Human factors in computer systems: A review of the literature (SAI-79-111-DEN). Englewood, CO: Science Applications, Inc. (NTIS AD A075 679)

*8. Williges, B. H., & Williges, R. C. (1984). Dialogue design considerations for interactive computer systems. In Muckler, F. A. (Ed.) Human factors review: 1984. Santa Monica, CA: Human Factors Society.

CROSS REFERENCES

25. Presenting numeric data in person-computer dialogue; 27. Presenting tabular data in person-computer dialogue

*Principal reference

30. ABBREVIATIONS AND ACRONYMS

KEY TERMS

TRUNCATION; COMMAND LANGUAGE; MNEMONICS; ALPHANUMERIC I/O

GENERAL DESCRIPTION

Terse and unambiguous abbreviations or acronyms, when used for input tasks, can increase user satisfaction and productivity by reducing keying time, lowering input error frequency, and reducing user involvement in error recovery procedures. For output displays, abbreviations reduce reading time and convey information in less physical display space. Unless thoughtfully designed, however, abbreviations (even simple truncation) can become confusing to the user and negate the potential performance benefits. Table 34 presents guidelines for successful design of abbreviations.

APPLICATIONS

Command language design; alphanumeric displays; text data entry.

CONSTRAINTS

- Words which are short (4 letters or less) should not be abbreviated unless a standard abbreviation exists (e.g., V for volt).
- Critical actions should not be made dependent upon a single keystroke response (e.g., Y for yes or N for no).
- Abbreviations are not suggested for displays (in general).

KEY REFERENCES

1. Brown, C. M., Burkleo, H. V., Mangelsdorf, J. E., Olsen, R. A., & Williams, A. R., Jr. (1981). Human factors engineering criteria for information processing systems. Sunnyvale, CA: Lockheed.
2. Ehrenreich, S. L. (1981). Query languages: Design recommendations derived from the human factors literature. Human Factors, 23, 709-725.
3. Galitz, W. O. (1981). Handbook of screen format design. Wellesley, MA: Q.E.D. Information Sciences.
4. Moses, F. L., & Ehrenreich, S. L. (1981). Abbreviations for automated systems. Proceedings of the Human Factors Society 25th Annual Meeting (pp. 132-135). Santa Monica, CA: The Human Factors Society.
5. Parrish, R. N., Gates, J. L., Munger, S. J., & Sidorsky, R. C. (1981). Development of design guidelines and criteria for user/operator transactions with battlefield automated systems. Volume IV: Provisional guidelines and criteria for the design of user/operator transactions (Draft Final Report, Phase I). Alexandria, VA: U.S. Army Research Institute.
6. Pew, R. W., & Rollins, A. M. (1975). Dialog specification procedures (rev. ed.) (Report No. 3129). Cambridge, MA: Bolt, Beranek and Newman, Inc.

TABLE 34. GUIDELINES FOR DESIGN OF ABBREVIATIONS AND ACRONYMS

General Guidelines

- Provide option for use of abbreviations or full command. (Refs. 1 & 5)
- Instruct user as to method used by system for selecting command abbreviations. (Ref. 2)
- Definition of data-entry codes or abbreviations by the user should be allowed. (Ref. 5)
- Contractions should not be used on electronic displays. (Refs. 1 & 4)

Abbreviation Design

Abbreviations should be:

- Limited to one per word. (Ref. 1)
- Considerably shorter than the original term. (Refs. 1 & 2)
- Mnemonically meaningful. (Refs. 1, 2, & 4)
- Distinctive to avoid confusion. (Refs. 1 & 3)
- Composed of unrestricted alphabetic sets when alphabetic data-entry is required. (Ref. 8)
- Consistent with unabbreviated command input. (Refs. 1 & 7)
- Simple truncation when used with command names. (Ref. 2)

Expansion of Abbreviations

- Abbreviations should be permitted in text entry and expanded later by the computer. (Ref. 1)

*7. Ramsey, H. R., & Atwood, M. E. (1979). Human factors in computer systems: A review of the literature (SAI-79-111-DEN). Englewood, CO: Science Applications Inc. (NITS AD A075 679).

8. Smith, S. L. (1981). Man-machine interface (MMI) requirements definition and design guidelines: A progress report (ESD-TR-81-113). Bedford, MA: The MITRE Corp. (NTIS No. AD A096 705).

9. Smith, S. L., & Aucella, A. F. (1983). Design guidelines for the user interface to computer-based information systems (ESD-TR-83-122). Bedford, MA: The MITRE Corp.

10. Williges, B. H., & Williges, R. C. (1983). Dialogue design considerations for interactive computer systems. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: Human Factors Society.

CROSS REFERENCES

26. Presenting text data in person-computer dialogue; 27. Presenting tabular data in person-computer dialogue; 29. Information coding in person-computer dialogue; 31. Prompting in person-computer dialogue; 33. Guidelines for multiple-frame displays; 34. Design guidelines for multiple-level displays

*Principal reference

31. PROMPTING IN PERSON-COMPUTER DIALOGUE

KEY TERMS

CURSOR FORMS; COMMAND LANGUAGE; INPUT PROMPTS

GENERAL DESCRIPTION

Prompting, regardless of form, provides a cue for required user inputs in person-computer dialogue. The effectiveness of prompting can be enhanced by designing the prompts to be clear and understandable, emphasized by highlighting, uniqueness and consistent location. Table 35 provides recommended prompt forms for various input formats.

TABLE 35. INPUT FORMAT AND RECOMMENDED PROMPT FORMS

INPUT FORMAT	PROMPT FORM
General Purpose	Commentary on Screen
General Purpose	Selectively Illuminating Function Keys
Positional Data	Tracking Cross
Text String	Blinking Cursor
Numerical Data	Quantitative Scale/Dial

APPLICATIONS

System-initiated requests for information to be input by user; structuring of command languages where used by inexperienced users.

CONSTRAINTS

- Prompting form should be selected as a function of desired input-type.

KEY REFERENCES

*1. Engel, S. E., & Granda, R. E. (1975). Guidelines for man/display interfaces (00.2720). Poughkeepsie, NY: IBM.

*Principal reference

2. Foley, J. D., & Wallace, V. L. (1974). The art of graphic man-machine conversation. Proceedings of the IEEE, 62(4), 462-471.

*3. Williges, B. H., & Williges, R. H. (1984). Dialogue design considerations for interactive computer systems. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: The Human Factors Society.

CROSS REFERENCES

21. Design and control of cursors; 32. Screen layout and structuring of person-computer dialogue displays

*Principal reference

32. SCREEN LAYOUT AND STRUCTURING OF PERSON-COMPUTER DIALOGUE DISPLAYS

KEY TERMS

DISPLAYS; FRAME DESIGN; DATA ENTRY; SMALL SCREEN DISPLAYS

GENERAL DESCRIPTION

The structuring of screen layout provides the designer with an opportunity to utilize the available display format for presentation of information which corresponds with the limits of human perception and memory. Display of too much information at one time can confuse users and tax the user's memory. The resulting user behaviors include frustration, a high frequency of errors, and (perhaps) eventual refusal to use the system.

Two types of display structuring should be considered: perceptual organization of data displays and sequential and/or hierarchical organization. Table 36 provides a series of guidelines focusing on functional grouping and display consistency concepts which provide increased user awareness of the perceptual organization. Criteria for functional grouping can range from arbitrary, yet consistent, organization to design based on frequency of usage or optimal logic flow. Details for individual frame design are provided in the cross references listing, according to data type.

TABLE 36. GUIDELINES FOR SCREEN LAYOUT AND STRUCTURING
(Source: Williges & Williges, 1984)

Windowing and Partitioning of Display

- The display should not be divided into many small windows. (Refs. 2 & 3)
- The user should be permitted to divide the screen into windows or functional areas of an appropriate size for the task. (Ref. 6)
- Dashed lines may be used to segment the display. (Ref. 4)
- The unused areas should be used to separate logical groups, rather than having all the unused area on one side of the display. (Ref. 1)
- In data entry and retrieval tasks, the screen should be functionally partitioned into different areas to discriminate among different classes of information for commands, status messages, and input fields. (Refs. 3 & 5)
- To enhance important or infrequent messages and alarms, they should be placed in the central field of vision relative to the display window. (Refs. 2 & 10)

TABLE 36. GUIDELINES FOR SCREEN LAYOUT AND STRUCTURING (Cont.)
(Source: Williges & Williges, 1984)

Organization of Fields

- The organization of displayed fields should be standardized. Functional areas should remain in the same relative location on all frames. This permits the users to develop spatial expectancies. For example, functional areas reserved for a particular kind of data should remain in the same relative display location throughout the dialogue. (Refs. 1, 2, 3, & 7)
- For data-entry dialogues, an obvious starting point in the upper-left corner of the screen should be provided. (Ref. 3)
- To avoid clutter, data should be presented using spacing, grouping and columns to produce an orderly and legible display. (Refs. 1 & 3)
- Data should be arranged in logical groups: sequentially, functionally, by importance, or by frequency. (Ref. 1)
- Logically related data should be clearly grouped and separated from other categories of data. On large, uncluttered screens, the display or functional areas should be separated by blank spaces (3-5 rows and/or columns). On smaller and/or more cluttered screens, structure can be defined by other coding techniques, such as using different surrounding line types, line widths, intensity levels, geometric shapes, color, etc. (Refs. 2, 3, & 10)
- Data should be arranged on the screen so that the observation of similarities, differences, trends, and relationships is facilitated for the most common uses. (Ref. 1)

Instructions and Supplemental Information

- In computer-initiated dialogues, each display page should have a title that indicates the purpose of the page. (Ref. 8)
- Instructions should stand out. For example, instructions may be preceded by a row of asterisks. (Refs. 1 & 4)
- Instructions on how to use a data-entry screen should precede the screen or appear at the top of the test. (Ref. 3)
- Instructions concerning how to process a completed data-entry screen should appear at the bottom of the screen. (Ref. 3)
- Symmetrical balance should be maintained by centering titles and graphics. (Ref. 3)
- In data entry and retrieval tasks, the last four lines on each display page should be reserved for messages, to indicate errors, communication links, or system status. (Ref. 8)
- When command language is used for control input, an appropriate entry area should be provided in a consistent location on every display, preferably at the bottom of the screen if the cursor can be conveniently moved there. (Ref. 9)
- Displays should be designed so that information relevant to sequence control should be distinctive in position and/or format. (Ref. 9)
- Frequently appearing commands should appear in the same area of the display at all times. (Ref. 2)

APPLICATION

Format of information displays; small screen displays (≤4000 characters).

CONSTRAINTS

- Guidelines may not be based on empirically validated research.
- Only required information should be displayed to avoid information overload or display clutter. Additional information should be available on user request.

KEY REFERENCES

1. Brown, C. M., Burkleo, H. V., Mangelsdorf, J. E., Olsen, R. A., & Williams, A. R., Jr. (1981). Human factors engineering criteria for information processing systems. Sunnyvale, CA: Lockheed.
2. Engel, S. E., & Granda, R. E. (1975). Guidelines for man/display interfaces (00.2720). Poughkeepsie, NY: IBM.
3. Galitz, W. O. (1981). Handbook of screen format design. Wellesley, MA: Q.E.D. Information Sciences.
4. Martin, J. (1973). Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.
5. Miller, L. A., & Thomas, J. C., Jr. (1976). Behavioral issues in the use of interactive systems (RC 6326). Yorktown Heights, NY: IBM.
6. Newman, W. M., & Sproull, R. F. (1979). Principles of interactive computer graphics. New York, NY: McGraw Hill.
7. Parrish, R. N., Gates, J. L., Munger, S. J., & Sidorsky, R. C. (1981). Development of design guidelines and criteria for user/operator transactions with battlefield automated systems. Volume IV: Provisional guidelines and criteria for the design of user/operator transactions (Draft Final Report, Phase I). Alexandria, VA: U. S. Army Research Institute.
8. Pew, R. W., & Rollins, A. M. (1975). Dialog specification procedures (3129). Cambridge, MA: Bolt, Beranek and Newman.
9. Smith, S. L. (1981). Man-machine interface (MMI) requirements definition and design guidelines: A progress report (ESD-TR-81-113). Bedford, MA: MITRE. (NTIS No. AD A096 705)
10. Tullis, T. S. (1981). An evaluation of alphanumeric, graphic, and color information displays. Human Factors, 23, 541-550.

*11. Williges, B. H., & Williges, R. C. (1984). Dialogue design considerations for interactive computer systems. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: Human Factors Society.

---

*Principal reference

CROSS REFERENCES

17. Data entry displays; 21. Design and control of cursors; 25. Presenting numeric data in person-computer dialogue; 26. Presenting text data in person-computer dialogue; 27. Presenting tabular data in person-computer dialogue; 28. Graphics in person-computer dialogue; 29. Information coding in person-computer dialogue; 30. Abbreviations and acronyms; 31. Prompting in person-computer dialogue; 33. Guidelines for multiple-frame display design; 34. Design guidelines for multiple-level displays; 35. Windowing versus scrolling on visual display terminals

33. GUIDELINES FOR MULTIPLE-FRAME DISPLAY DESIGN

KEY TERMS

INTERFRAME CONSIDERATIONS; MULTI-FRAME; HIERARCHICAL STRUCTURES; SEQUENCE CONTROL; BRANCHING MENUS

GENERAL DESCRIPTION

The guidelines were synthesized from known human factors/psychological principles, experimental studies, customer/user comments, and informal studies. Table 37 lists guidelines for display of multiple frames in series to minimize dependence on user's memory.

APPLICATIONS

Use of more than one frame for data display or entry; sequence control in hierarchical or branching menus.

CONSTRAINTS

- Guidelines are not standards: consider modifications required by specific system/application needs.
- Guidelines cannot provide quantification without empirical study.
- Recent systematic studies of interface design may provide more detailed/updated guidelines.
- Multiple frame display design must also consider single frame display guidelines.
- Pilot testing is desirable to validate guidelines in application usage.

KEY REFERENCES

1. Engel, S. E., & Granda, R. E. (1975). Guidelines for man/display interfaces (00.2720). Poughkeepsie, NY: IBM Poughkeepsie Laboratory.

CROSS REFERENCES

34. Design guidelines for multiple-level menus

TABLE 37. LISTING OF GUIDELINES FOR MULTIPLE-LEVEL DISPLAYS
(Source: Engel & Granda, 1975)

- Provide present and maximum locations on viewed portion when scrolling a large logical frame. Example: "Line 72 of 117"

- Provide user control of amount, format and complexity of displayed system information.

- Display prose text in upper and lower case. Labels, titles or attention-getting message, use upper case only.

Not:	But:
ALL UPPER CASE TEXT IS HARDER TO READ THAN A MIXTURE OF UPPER AND LOWER CASE.	Normal reading is easier if the text is in both upper and lower case.

- Minimize users' need to remember data from frame to frame; provide visible audit trail of choices.

First Frame	Second Frame	Third Frame
Pick one: FORTRAN PL/I GPSS ...	GPSS Pick one: ADVANCE TRANSFER UNLINK ...	GPSS - TRANSFER Pick one: Fractional Pick Unconditional ...

- Use consistent meanings and context of technical words. Consider user's viewpoint, not programmer's.

- Keep lists small (4-6 items) to increase comprehension of listed items.

- Standardize spatial position of appearing/disappearing screen items:

  a. Commands in same location on screen

  b. List items in same location in list regardless of number of items.

- Maintain system control of essential data, text, formats, etc., not user control.

34. DESIGN GUIDELINES FOR MULTIPLE-LEVEL DISPLAYS

KEY TERMS

MENU DIALOGUE; MULTI-PAGE DISPLAYS; MULTI-FRAME

GENERAL DESCRIPTION

Displays with multiple-levels which the user must negotiate to accomplish a task must provide mechanisms for accuracy and ease-of-use. Table 38 provides a checklist of critical design considerations.

TABLE 38. MULTIPLE-LEVEL DISPLAY CONSIDERATIONS
(Source: Hendricks et al., 1982)

Display Levels	Yes	Not Applicable	Not Known	No
If the system has multiple display levels, does the system:				
a. Minimize the number of levels required?	___	___	___	___
b. Provide priority access to the more critical display levels?	___	___	___	___
c. Provide the user with information about the current position within the sequence of levels?	___	___	___	___
d. Insure similarity, wherever possible, between display formats at each level?	___	___	___	___
e. Supply all data relevant to making an entry on one display frame?	___	___	___	___

APPLICATIONS

Interactive dialogue requiring use of multiple dialogue levels; hierarchical or branching dialogue; computer initiated questioning, form-filling or menu selection dialogue.

CONSTRAINTS

- Guidelines are not standards: consider modifications required by specific system/application needs.
- Guidelines cannot provide quantification without empirical study.
- Multiple frame display design must also consider single frame display guidelines.
- Pilot testing is desirable to validate guidelines for specific applications.

KEY REFERENCES

1. Henricks, D., Kilduff, P., Brooks, P., Marchak, B., & Doyle, B. (1982). Human engineering guidelines for management information systems. Alexandria, VA: U.S. Army Materiel Development and Readiness Command.

CROSS REFERENCES

33. Guidelines for multiple-frame display design

35. WINDOWING VERSUS SCROLLING ON VISUAL DISPLAY TERMINALS

KEY TERMS

VIDEO DISPLAY INFORMATION; DATA DISPLAY MOVEMENTS; HIERARCHIC DATA DISPLAYS

GENERAL DESCRIPTION

Two conceptualizations of data display restriction are common when available data exceeds the display capability of a video display terminal (VDT): (1) windowing and (2) scrolling. The windowing concept allows selection of views of "stationary" data, whereas scrolling provides a movement of the data observable through a "stationary" VDT. Figure 10 diagramatically shows differences between windowing and scrolling.

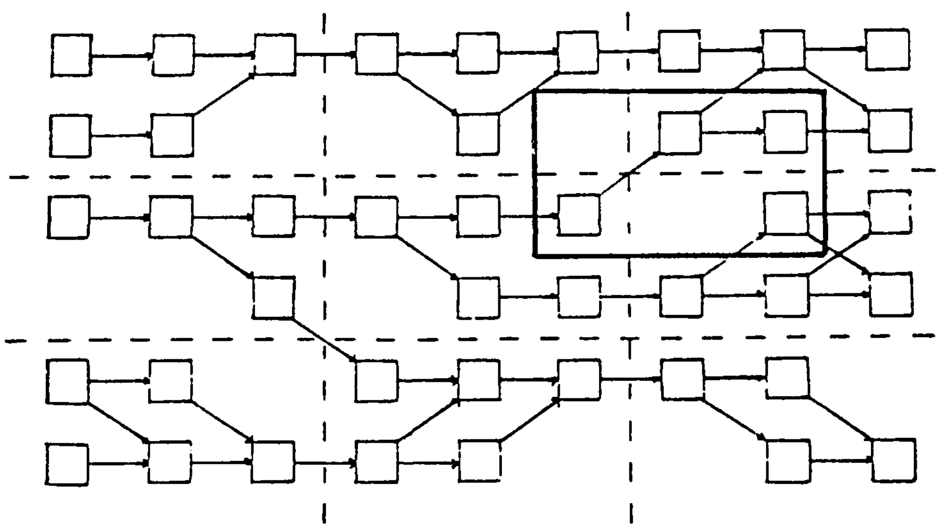


Figure 10. Data network overview showing windowing page boundaries (dashed lines) and an example scrolling page (solid lines). (Source: Brooke and Duncan, 1983)

"Intuitive" advantages of each concept have resulted in the adoption of both types of data displays in various systems. Empirical research tends to indicate a population stereotype in favor of, and a superiority of, the windowing concept. Conclusive findings in applied problem-solving tasks, however, are pending. Windowing is believed to provide a more optimal outline of the overall structure, thus reducing the memory load on the user. Table 39 describes the major finding of windowing versus scrolling.

TABLE 39. MAJOR FINDINGS OF WINDOWING VERSUS SCROLLING RESEARCH

Consistent user performance is facilitated by restricted views, rather than unrestricted views, of system information.

When allowed to choose system modes, more novice users chose window mode.

Window displays are more efficient than scrolling displays; users performed tasks:

- in less time
- with fewer number of moves
- with less error

Explanation and demonstration of display modes does not affect performance.

The use of keytop scroll figures , as opposed to arrows $\boxed{\rightarrow}$, does not improve performance.

APPLICATIONS

Selection of video display modes; engineering data base search strategies.

METHODOLOGY

Stimulus and Viewing Conditions

Study 1 (Ref. 2): • Display of number vector (horizontal) and letter vector (vertical) intersecting at "12-13" and "L-M"; • initial position: intersection.

Study 2 (Ref. 1): • Logic network - four rows x six columns; • display restricted by windows or scrolling (see Fig.); • initial position: top right cell.

Procedure and Experimental Design

Study 1 (Ref. 2):

- Independent variables: display concept (Self-defined - Observers (Os) defined mode in which the system operated. No explanation of the window or scroll concept was given; Window/concept - Os were given an explanation and demonstration of the window concept and were constrained to operate in the window mode; Window/no concept - Os were constrained to operate in the window mode, but were given no explanation or demonstration of the window concept; Scroll/concept - Os were given an explanation and demonstration of the scroll concept and were constrained to operate in the scroll mode; Scroll/no concept - Os were constrained to operate in the scroll mode without an explanation or demonstration of the scroll concept).

- Dependent variables: Time for problem solution; number of moves.
- O's task: Move display to display requested data (example: show "x" and "20").
- Os: 28 high school students.

Study 2 (Ref. 1):

- Independent variables: Type of display (whole, windowing, scrolling), ability on pre-test.
- Dependent variables: Solution time, efficiency.
- O's task: logic tree fault finding.
- Os: 23 high school and undergraduate college students.

EXPERIMENTAL RESULTS

Study 1 (Ref. 2):

- Significantly greater number of novice users (79%) chose windowing mode.
- Windowing groups performed significantly faster and with fewer number of moves overall.
- Explanation and description of the appropriate concept did not have a significant affect on performance.
- Type of keytop marking did not have a significant effect on performance (determined in separate study).

Study 2 (Ref. 1):

- Windowing format improved the efficiency of the fault diagnosis task rather than ensuring correct problem solution.
- Restricting the proportion of information displayed substantially restricts between subject variance in the fault finding measures.

CONSTRAINTS

- Conclusions are based on limited empirical study.
- Applicability of these findings to experienced users of computers or specific systems is unknown.

KEY REFERENCES

*1. Brooke, J. B., & Duncan, K. D. (1983). A comparison of hierarchically paged and scrolling displays for fault-finding. Ergonomics, 26(5), 465-477.

*2. Bury, K. F., Boyle, J. M., Evey, R. J., & Neal, A. S. (1982). Windowing versus scrolling on a visual display terminal. Human Factors, 24(4), 385-394.

CROSS REFERENCES

19. Sequence control in person-computer dialogue; 21. Design and control of cursors

---

*Principal reference

36. GUIDELINES FOR USE OF NONCRITICAL AUDITORY SIGNALS

KEY TERMS

ALARMS; BELL

GENERAL DESCRIPTION

Auditory signals can be used to supplement interactive visual displays in critical and noncritical situations. They are best, however, for critical situations. Auditory signals should be used in situations where visual task loading on the operator is high or when visually presented messages may be overlooked or misinterpreted. For example, when system response is greater than 15 sec, an auditory signal can indicate the "system ready" state. This allows the user to use that time productively for other tasks without being required to monitor the visual display. Table 40 lists general guidelines which define desirable characteristics of noncritical auditory signals.

TABLE 40. GUIDELINES FOR DESIGN OF AUDITORY SIGNALS
(Source: Hendricks et al., 1982)

- The auditory signal should be used to alert and direct the user's attention to the appropriate visual display.
- The optimum type of signal ought to be carefully evaluated, so that while not startling or interfering with others in the immediate area, it is readily noticed by the user. Because of variable background noises, the intensity should be adjustable.
- The intensity, duration, and source location of the signal should be selected to be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal area.
- Auditory signals should be intermittent in nature, allowing the user sufficient time to respond. The signal should be automatically shut off by user response action.
- Auditory signals should be sounded by system failures.
- Non-critical auditory signals should be capable of being turned off at the discretion of the user.

APPLICATIONS

Attention-getting; announcing changes in system state; declaring system or I/O failure.

CONSTRAINTS

- Guidelines may not have been empirically validated.

KEY REFERENCES

1. Hendricks, D., Kilduff, P., Brooks, P., Marshak, R., & Doyle, B. (1982). Human engineering guidelines for management information systems. Alexandria, VA: U.S. Army Materiel Development and Readiness Command.

CROSS REFERENCES

13. System response time and the effect on user performance and satisfaction

BIBLIOGRAPHY

Alden, D. G., Daniels, R. W., & Knarick, A. F. (1982). Keyboard design and operation: A review of the major issues. Human Factors, 14(4), 275-293.

Allen, R. B., & Scerbo, M. W. (1983). Details of command language keystrokes. ACM Transactions on Office Information Systems, 1(2), 159-178.

Anderson, R. H., & Gillogy, J. J. (1976, February). Rand intelligent terminal agent (RITA): Design philosophy (R-1809-ARPA). Santa Monica, CA: Rand Corp.

Bailey, R. W. (1972). Testing manual procedures in computer-based business information systems. Proceedings of the 16th Annual Meeting of the Human Factors Society, Santa Monica, CA: Human Factors Society, 395-401.

Bailey, R. W. (1983). Human error in computer systems. New York: Prentice-Hall.

Baker, J. D. (1972, June). Quantitative modeling of human performance in information systems (Technical Research Note 232). U.S. Army Behavior and Systems Laboratory. (NTIS AD-746 096)

Barnard, P., Hammond, N. V., MacLean, A., & Morton, J. (1982). Learning and remembering interactive commands. In Proceedings of Human Factors in Computer Systems (pp. 2-7). New York: Association for Computing Machinery.

Barnard, P. J., Hammond, N. V., Morton, J., Long, J. B., & Clark, I. (1981). Consistency and compatibility in human-computer dialogue. International Journal of Man-Machine Studies, 15(1), 87-134.

Bates, M., & Vittal, J. (1982). Tools for the development of systems for human factors experiments: An example for the SSA. IEEE Transactions on Systems, Man and Cybernetics, 12(2), 133-148.

Black, J. B., & Moran, T. P. (1982). Learning and remembering command names. In Proceedings of Human Factors in Computer Systems (pp. 8-11). New York: Association for Computing Machinery.

Bo, K. (1982, November). Human-computer interaction. Computer Magazine, pp. 9-11.

Boff, K. R. (1982, 18-20 May). Integrated perceptual information for designers. Proceedings of the IEEE National Aerospace & Electronics Conference (pp. 430-434). New York: Institute of Electrical and Electronic Engineers.

Boies, S. J. (1974). User behavior on an interactive computer system. IBM Systems Journal, 13(1), 2-18.

Botterill, J. H. (1982). The design rationale of the system/38 user interface. IBM Systems Journal, 23(4), 384-423.

Britton, E., Lipscomb, J., & Pique, M. (1978). Making nested rotations convenient for the user. Computer Graphics, 3, 222-227.

Brown, C. M., Burkleo, H. V., Mangelsdorf, J. E., Olsen, R. A., & Williams, A. R., Jr. (1981). Data base standards and procedures. Sunnyvale, CA: Lockheed Missiles and Space Company.

Bury, K. F., Boyle, J. M., Evey, R. J., & Neal, A. S. (1982). Windowing versus scrolling on a visual display terminal. Human Factors, 24(4), 385-394.

Butterbaugh, L. C. (1982). Evaluation of alternative alphanumeric keying logics. Human Factors, 24(5), 521-533.

Cakir, A., Hart, D. J., & Stewart, T. F. M. (1980). Visual display terminals: A manual covering ergonomics, workplace design, health and safety, task organization. New York: Wiley.

Calhoun, G. L. (1978). Control logic design criteria for multifunction switching devices. Proceedings of the 22nd Human Factors Society Annual Meeting (pp. 383-387). Santa Monica, CA: Human Factors Society.

Card, S. K., English, W. K., & Burr, B. J. (1978). Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT. Ergonomics, 21, 601-613.

Card, S. K., Moran, T. P., & Newell, A. (1983). The psychology of human-computer interaction. Hillsdale, NJ: Lawrence Erlbaum.

Carey, T. (1982, November). User differences in interface design. Computer Magazine, pp. 14-20.

Carroll, J. M. (1979). Natural strategies in naming (Research Report RC 32557). Yorktown Heights, NY: IBM.

Carroll, J. M. (1982, November). The adventure of getting to know a computer. Computer Magazine, pp. 49-58.

Carroll, J. M., & Thomas, J. C. (1982). Metaphor and the cognitive representation of computing systems. IEEE Transactions on Systems, Man, and Cybernetics, SMC-12(2), 107-116.

Chamberlain, R. G. (1975, November). Conventions for interactive computer programs. Interfaces, 6(1), 77-82.

Chapanis, A. (1975). Interactive human communication. Scientific American, 232, 36-42.

Chariton, D. R. (1976). Man-machine interface design for timesharing systems. Proceedings of the Annual Conference of the Association for Computing Machinery (pp. 362-366). New York: Association for Computing Machinery.

Christ, R. E. (1975). Review and analysis of color coding: Research for visual displays. Human Factors, 17, 542-570.

Clapp, J. A., & Hazle, M. (1978, March). Building blocks for C3 systems (ESD-TR-77-360). Hanscom AFB, MA: Electronic Systems Division, AFSC. (NTIS AD-A052 568)

Codd, E. F. (1974). Seven steps to rendezvous with the casual user. In J. W. Klimbie & K. L. Koffeman (Eds.), Proceedings of the IFIP TC-2 working conference on data base management systems. Amsterdam, North-Holland.

Coffey, J. L. (1961). A comparison of vertical and horizontal arrangements of alpha-numerical materials. Human Factors, 3, 93-98.

Coombs, M. J., & Alty, J. L. (1981). Computing skills and the user interface. New York: Academic Press.

Cooper, R. G., Marston, P. T., Durrett, J., & Stimmel, T. (1982, April). A human factors case study based on th. ᵔM personal computer. Byte Magazine, pp. 56-72.

Cuff, R. N. (1980). On casual users. International Journal of Man-Machine Studies, 12, 163-187.

Durding, B. M., Becker, C. A., & Gould, J. D. (1977). Data organization. Human Factors, 19, 1-14.

Dwyer, B. (1981). A user-friendly algorithm. Communications of the ACM, 24(9), 556-561.

Earl, W. K., & Goff, J. D. (1965). Comparison of two data entry methods. Perceptual and Motor Skills, 20, 369-384.

Eason, K. (1983). Methodological issues in the study of human factors in teleinformatic systems. Behaviour and Information Technology, 2(4), 357-364.

Eastman Kodak Company (1983). Ergonomic design for people at work. Belmont, CA: Lifetime Learning Publications.

Ehrenreich, S. L. (1981). Query languages: Design recommendations derived from the human factors literature. Human Factors, 23(6), 709-725.

Embley, D. W., Lan, M. T., Leinbaugh, D. W., & Nagy, G. (1978). A procedure for predicting program editor performance from the user's point of view. International Journal of Man-Machine Studies, 10(6), 639-650.

Embley, D. W., & Nagy, G. (1981). Behavioral aspects of text editors. ACM Computing Surveys, 13(1), 34-70.

Engel, S. E., & Granda, R. E. (1975, December). Guidelines for man/display interfaces (Technical Report TR 00.2720). Poughkeepsie, NY: IBM Poughkeepsie Laboratory.

Fenchel, R. S., & Estrin, G. (1982). Self-describing systems using integral help. IEEE Transactions on Systems, Man and Cybernetics, 12(2), 162-167.

Feyock, S. (1977). Transition diagram-based CAI/HELP systems. International Journal of Man-Machine Systems, 9, 399-413.

Fields, A. F., Maisano, R. E., & Marshall, C. F. (1978, September). A comparative analysis of methods for tactical data inputting (Technical Paper 327). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences (NTIS AD A060 562)

Fitter, M. (1979). Towards more "natural" interactive systems. International Journal of Man-Machine Systems, 11(3), 339-350.

Fjalestad, J. (1983). Data communication - some interorginizational aspects. Behaviour and Information Technology, 2(4), 327-333.

Foley, J. D., & Wallace, V. L. (1974, April). The art of natural graphic man-machine conversation. Proceedings of the IEEE, 62(4), 462-471.

Gade, P. A., Fields, A. F., Maisano, R. E., Marshall, C. F., & Alderman, I. N. (1981). Data entry performance as a function of method and instructional strategy. Human Factors, 23, 199-210.

Galitz, W. O. (1980). Human factors in office automation. Life Office Management Association.

Galitz, W. O. (1981). Handbook of screen format design. Wellesley, MA: Q.E.D. Information Sciences.

Gallaway, G. R. (1981). Response times to user activities in interactive man/machine computer systems. Proceedings of the Human Factors Society 25th Annual Meeting (pp. 754-758). Santa Monica, CA: Human Factors Society.

Goodwin, N. C. (1978, March). Man-machine interface characteristics. Published as an Appendix in J. S. Clapp, & M. Hazle, Building blocks for C3. (NTIS AD A052 568)

Gould, J. D. (1981). Composing letters with computer-based text editors. Human Factors, 23(5), 593-606.

Gould, J. D., & Ascher, R. N. (1975, February). Use of an IQF-like query language by non-programmers (Research Report RC 5279). Yorktown Heights, NY: IBM, Thomas J. Watson Research Center.

Gould, J. D., & Lewis, C. (1983). Designing for usability - key principles and what designers think. Proceedings of CHI '83 Human Factors in Computing (pp. 50-53). New York: Association for Computing Machinery.

Gould, J. D., Lewis, C. & Becker, C. A. (1976, April). Writing and following procedural, descriptive, and restricted syntax language (RC 5943). Yorktown Heights, NY: IBM, Thomas J. Watson Research Center. (NTIS AD A041 289)

Gram, C., & Hertweck, F. (1975). Command languages: Design considerations and basic concepts. In C. Unger (Ed.), Command languages. Amsterdam, North-Holland.

Granda, R. E., & Finkelman, J. M. (Eds.). (1977). The role of human factors in computers. New York: The City University of New York.

Green, E. E. (1976). Message design -- graphic display strategies for instruction. Proceedings of the Annual Conference of Association for Computing Machinery (pp. 144-148). New York: Association for Computing Machinery.

Green, T. R. G., Payne, S. J., Morrison, D. L., & Shaw, A. (1983). Friendly interfacing to simple speech recognizers. Behaviour and Information Technology, 2(1), 23-38.

Greenblatt, D., & Waxman, J. (1978, June). User oriented query language design. In Proceedings of Human Factors and Computer Science Symposium (pp. 87-102). Santa Monica, CA: Human Factors Society.

Hannemyr, G. (1983). Human factors standards: The design of conceptual language interfaces to open computer network application and management systems. Behaviour and Information Technology, 2(4), 345-356.

Hansen, W. J. (1971). User engineering principles for interactive systems. AFIPS Conference Proceedings, 39, 523-532.

Heidorn, G. E. (1976). Automatic programming through natural language dialogue: A survey. IBM Journal of Research and Development, 20, 302-313.

Hemenway, K. (1982). Psychological issues in the use of icons in command menus. Proceedings of CHI '83 Human Factors in Computer Systems (pp. 20-23). New York: Association for Computing Machinery.

Hill, I. D. (1972). Wouldn't it be nice if we could write programs in ordinary English - or would it? The Computer Bulletin, 16, 306-312.

Hiltz, S. R., & Turoff, M. (1978). The network nation. Reading, MA: Addison-Wesley.

Hollnagel, E. (1978). Qualitative aspects of man-machine communication. Roskilde, Denmark: RISØ National Laboratory.

Hollnagel, E., & Woods, D. D. (1983). Cognitive systems engineering: New wine in new bottles. International Journal of Man-Machine Studies, 18, 583-600.

Hornbuckle, G. D. (1967). The computer graphics/user interface. IEEE Transactions on Human Factors in Electronics, HFE-8, 17-25.

Jacob, R. J. K. (1983). Using formal specifications in the design of a human-computer interface. Communications of the ACM, 26(4), 259-264.

Jensen, W., & Eason, K. (1983). International studies of human factors in teleinformatics. Behaviour and Information Technology, 2(4), 301-311.

Jones, P. F. (1978). Four principles of man-computer dialogue. Computer-Aided Design, 10(3), 262-265.

Kantowitz, B. H., & Sarkin, R. D. (1983). Human factors: Understanding people-system relationships. New York: John Wiley & Sons.

Katter, R. V., Potash, L. M., & Halpin, S. M. (1978). MIQSTURE: Design for a mixed initiative structure with task and user related elements. Proceedings of the Human Factors Society 22nd Annual Meeting (pp. 175-179). Santa Monica, CA: Human Factors Society.

Kelly, M. J. (1975, August). Studies in interactive communication: Limited vocabulary natural language dialogue (Technical Report 3). Baltimore, MD: Johns Hopkins University, Dept. of Psychology. (NTIS AD A019 198)

Kennedy, T. C. (1975). Some behavior factors affecting the training of naive users of an interactive computer system. International Journal of Man-Machine Studies, 7, 817-834.

Kennedy, T. C. S. (1974). The design of interactive procedures for man-machine communication. International Journal of Man-Machine Studies, 6, 309-334.

Klemmer, E. T. (1971). Keyboard entry. Applied Ergonomics, 2, 2-6.

Leavenworth, B. M., & Sammet, J. E. (1974, January). An overview of non-procedural languages (Research Report RC 4685). Yorktown Heights, NY: IBM, Thomas J. Watson Research Center.

Ledgard, H., Singer, A., & Whiteside, J. (1981). Directions in human factors in interactive systems. New York: Springer-Verlag.

Ledgard, H., Whiteside, J. A., Singer, A., & Seymour, W. (1980). The natural language of interactive systems. Communications of the ACM, 23(10), 556-563.

Long, J., Hammond, N., Barnard, P., Morton, J., & Clark, I. (1983). Introducing the interactive computer at work: The users' views. Behaviour and Information Technology, 2(1), 39-106.

Marcus, R. S. (1982). User assistance in bibliographic retrieval networks through a computer intermediary. IEEE Transactions on Man, Systems and Cybernetics, 12(2), 116-133.

Martin, J. (1973). Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall.

Martin, T. H. (1973). The user interface in interactive systems. In C. A. Caudra, & A. W. Luke (Eds.), Annual review of information science and technology, 8, 203-219.

Mayer, R. E. (1981). The psychology of how novices learn computer programming. ACM Computing Surveys, 12(1), 121-141.

McCann, P. H. (1983). Methods of improving the user-computer interface (Report No. 17-83-8). San Diego, CA: Naval Personnel Research and Development Center.

McCauley, M. E. (1984). Human factors in voice technology. In F. A. Muckler (Ed.), Human factors review: 1984. Santa Monica, CA: Human Factors Society.

Meadow, C. T. (1970). Man-machine communication. New York: John Wiley & Sons.

Miller, L. A. (1978, October). Behavioral studies of the programming process (Research Report RC 7367). Yorktown Heights, NY: IBM, Thomas J. Watson Research Center.

Miller, L. A., & Thomas, J. C., Jr. (1976, December). Behavioral issues in the use of interactive systems (Research Report RC 6326). Yorktown Heights, NY: IBM, Thomas J. Watson Research Center. (Also International Journal of Man-Machine Studies, 1977, 9, 509-536.)

Miller, R. B. (1968). Response time in man-computer conversational transactions. AFIPS Conference Proceedings, 33, 267-277.

Moran, T. P. (1981). The command language grammar: A representation for the user interface of interactive computer systems. International Journal of Man-Machine Studies, 15(1), 3-50.

Moses, F. L., & Potash, L. M. (1979, August). Assessment of abbreviation methods for automated tactical systems (Technical Report 398). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (NTIS AD A077 840)

Mozeico, H. (1982). A human/computer interface to accommodate user learning stages. Communications of the ACM, 25(2), 100-104.

NASA (1979, January). Spacelab experiment computer application software (ECAS) display design and command usage guidelines (Report MSFC-PROC-711). Huntsville, AL: George C. Marshall Space Flight Center.

Nawrocki, L. H., Strub, M. H., & Cecil, R. M. (1973, August). Error categorization and analysis in man-computer communication systems. IEEE Transactions on Reliability, R22(3).

Newman, J. (1977). The processing of two types of command statements: A contribution to cognitive ergonomics. IEEE Transactions on Systems, Man and Cybernetics, 7(12), 871-875.

Nickerson, R. S. (1976, October 14-15). On conversational interactions with computers. In S. Treu (Ed.), User-oriented design of interactive graphic systems, Proceedings of ACM/SIGGRAPH Workshop, Pittsburgh, PA.

Nickerson, R. S. (1980, December). Some human factors implications of the blurring of the line between communication and computation (Report No. 4577). Cambridge, MA: Bolt, Beranek and Newman, Inc.

Nickerson, R. S. (1981). Why interactive computer systems are sometimes not used by people who might benefit from them. International Journal of Man-Machine Studies, 15(4), 469-483.

Nickerson, R. S. (1982). Conclusion: Information technology and psychology: A retrospective look at some views of the future. In Kasschau, Lachman, & Laughery (Eds.), Information technology and psychology: Prospects for the future. New York: Praeger.

Nickerson, R. S., & Pew, R. W. (1971, June). Oblique steps toward the human-factors engineering of interactive computer systems. Published as an Appendix in M. D. Grignetti, D. C. Miller, R. S. Nickerson, & R. W. Pew, Information processing models and computer aids for human performance (Report No. 2190). Cambridge, MA: Bolt, Beranek and Newman, Inc. (NTIS AD 732 913)

Nickerson, R. S., & Pew, R. W. (1977, February). The C^3-system user, Vol. 1: A review of research on human performance as it relates to the design and operation of command, control, and communication systems (BBN Report No. 3459). Cambridge, MA: Bolt, Beranek and Newman, Inc.

Norman, D. A. (1981). The trouble with UNIX. Datamation, 139-150.

Norman, D. A. (1982). How to make computer systems that people will like to use: Steps toward a cognitive engineering. Proceedings of the Western Electronic Show and Convention.

Norman, D. A. (1983). Design rules based on analyses of human error. Communications of the ACM, 26(4), 254-258.

Norman, D. A., & Fisher, D. (1982). Why alphabetic keyboards are not easy to use: Keyboard layout doesn't much matter. Human Factors, 24(5), 509-519.

Palme, J. (1975, July). Interactive software for humans (Report FOA-C10029-M3(E5)). Stockholm: Swedish National Defense Research Institute.

Palme, J. (1979). A human-computer interface for non-computer specialists. Software - Practice and Experience, 9, 741-747.

Pechura, M. A. (1983). Comparing two microcomputer operating systems: CP/M and HDOS. Communications of the ACM, 26(3), 188-195.

Petrick, S. R. (1976). On natural language based computer systems. IBM Journal of Research and Development, 20, 314-325.

Pew, R. W., & Rollins, A. M. (1975). Dialog specification procedures (revised) (Report 3129). Cambridge, MA: Bolt, Beranek and Newman, Inc.

Pew, R. W., Rollins, A. M., & Williams, G. A. (1976). Generic man-computer dialogue specification: An alternative to dialogue specialists. Proceedings of the 6th Congress of the International Ergonomics Association (pp. 251-254). Santa Monica, CA: Human Factors Society.

Potash, L. M. (1979, July). Effects of retrieval term specificity on information retrieval from computer-based intelligence systems (Technical Report 379). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (NTIS AD A072 312)

Price, L. A. (1982). Thumb: An interactive tool for accessing and maintaining text. IEEE Transactions on Systems, Man and Cybernetics, 12(2), 155-161.

Ramsey, H. R., & Atwood, M. E. (1979, September). Human factors in computer systems: A review of the literature (Technical Report SAI-79-III-DEN). Englewood, CO: Science Applications, Inc. (NTIS AD A075 679)

Ramsey, H. R., Atwood, M. E., & Kirshbaum, P. J. (1978, May). A critically annotated bibliography of the literature of human factors in computer systems (Technical Report SAI-78-070-DEN). Englewood, CO: Science Applications, Inc. (NTIS AD A058 081)

Reisner, P. (1977). Use of psychological experimentation as an aid to development of a query language. IEEE Transactions on Software Engineering, SE-3, 218-229.

Reisner, P. (1981). Human factors studies of database query languages: A survey and assessment. ACM Computing Surveys, 13(1), 13-31.

Richtie, G. J., & Turner, J. A. (1975). Input devices for interactive graphics. International Journal of Man-Machine Studies, 7, 639-660.

Roberts, T., & Moran, T. (1983). The evaluation of text editors: Methodology and empirical results. Communications of the ACM, 26(4), 265-283.

Robertson, G, McCracken, D., & Newell, A. (1981). The ZOG approach to man-machine communications. International Journal of Man-Machine Studies, 14(4), 461-488.

Robinson, A., & Wilkins, D. (1982, November). Man-computer cooperation for action planning (SRI Project 1349). Menlo Park, CA: SRI International.

Root, R. T., & Sadacca, R. (1967). Man-computer communication techniques: two experiments. Human Factors, 9(6), 521-528.

Rosenberg, J. (1982). Evaluating the suggestiveness of command names. In Proceedings of Human Factors in Computer Systems (pp. 12-16). New York: Association for Computing Machinery.

Rouse, W. B. (1975, June). Design of man-computer interfaces for on-line interactive systems. Proceedings of the IEEE, 63(6), 847-857.

Rouse, W. B. (1976). Adaptive allocation of decision making responsibility between supervisor and computer. In Sheridan & Johnnson (Eds.), Monitoring behavior and supervisory control. New York: Plenum Press.

Sackman, H. (1967). Computers, system science and evolving society. New York: John Wiley & Sons.

Sackman, H. (1970). Man-computer problem solving. Pennsauken, NJ: Auerbach.

Scapin, D. L. (1981). Computer commands in restricted natural language: Some aspects of memory and experience. Human Factors, 23(3), 365-375.

Scapin, D. L. (1982). Computer commands labelled by users versus imposed commands and the efffect of structuring rules on recall. In Proceedings of Human Factors in Computer Systems (pp. 17-19). New York: Association for Computing Machinery.

Shapiro, S. C., & Kwasny, S. C. (1975). Interactive consulting via natural language. Communications of the ACM, 18, 459-462.

Sheil, B. A. (1981). The psychological study of programming. ACM Computing Surveys, 13(1), 101-120.

Shneiderman, B. (1980). Software psychology: Human factors in computer and information systems. Cambridge, MA: Winthrop Publishing, Inc.

Shneiderman, B. (1981). A note on human factors issues of natural language interaction with database systems. Information Systems, 6, 125-129.

Shneiderman, B. (1982). Multiparty grammars and related features for defining interactive systems. IEEE Transactions on Systems, Man and Cybernetics, 12(2), 148-154.

Sime, M. E., & Coombs, M. J. (Eds.) (1983). Designing for human-computer communications. New York: Academic Press.

Sime, M. E., Green, T. R. C., & Guest, D. J. (1973). Psychological evaluation of two conditional constructions used in computer languages. International Journal of Man-Machine Studies, 5, 105-113.

Simpson, H. (1982, April). A human-factors style guide for program design. Byte Magazine, pp. 108-132.

Small, D. W., & Weldon, L. J. (1977, September). The efficiency of retrieving information from computers using natural and structured query languages (Technical Report SAI-78-655-WA). Arlington, VA: Science Applications, Inc.

Smith, D. C., Irby, C., Kimball, R., Verplank, B., & Harslen, E. (1982, April). Designing the STAR user interface. Byte Magazine, pp. 242-282.

Smith, H. T., & Green T. R. G. (Eds.) (1980). Human interaction with computers. New York: Academic Press.

Smith, S. L. (1962). Angular estimation. Journal of Applied Psychology, 46, 240-246.

Smith, S. L. (1963) Man-computer information transfer. In Howard, J. H. (Ed.), Electronic information display systems (pp. 284-299). Washington, DC: Spartan Books.

Smith, S. L. (1974, March). An on-line model of traffic control in a communications network (Technical Report MTR-2813). Bedford, MA: The MITRE Corporation.

Smith, S. L. (1976a, August). MAC air cargo data entry: 1. Preliminary analysis of alternative modes (ESD-TR-76-162). Hanscom AFB, MA: Electronic Systems Division, AFSC. (NTIS AD A029 013)

Smith, S. L. (1976b, June). MAC air cargo data entry: 5. Field testing an on-line terminal at the Dover Aerial Port (Technical Report MTR-3066-5). Bedford, MA: The MITRE Corporation.

Smith, S. L. (1980). Requirements definition and design guidelines for man-machine interface in C^3 system acquisition (ESD-TR-80-122). Hanscom AFB, MA: Electronic Systems Division, AFSC. (NTIS AD A087 258)

Smith, S. L. (1981). Man-machine interface (MMI) requirements definition and design guidelines: A progress report (Report No. ESD-TR-81-113). Bedford, MA: The Mitre Corporation. (NTIS AD A096 705)

Smith, S. L., & Aucella, A. F. (1983). Design guidelines for the user interface to computer-based information systems (ESD-TR-83-122). Bedford, MA: The Mitre Corporation.

Smith, S. L., & Goodwin, N. C. (1971). Alphabetic data entry via the Touch-Tone pad: A comment. Human Factors, 13(2), 189-190.

Smith, S. L., & Goodwin, N. C. (1979). Computer-generated speech and man-computer interaction. Human Factors, 12(2), 215-223.

Sondheimer, N. K., & Relles, N. (1982). Human factors and user assistance in interactive computing systems: An introduction. IEEE Transactions on Systems, Man and Cybernetics, 12(2), 102-107.

Steeb, R., Artof, M., Crooks, W. H., & Weltman, G. (1975). Man/machine interaction in adaptive computer-aided control: Final report (PATR-1008-75-12/31). Woodland Hills, CA: Perceptronics. (NTIS AD A021 323)

Steeb, R., Weltman, G., & Freedy, A. (1976). Man/machine interaction in adaptive computer-aided control: Human factors guidelines (PATR-1008-76-1/31). Woodland Hills, CA: Perceptronics, Inc. (NTIS AD 021 721)

Stevens, G. C. (1983). User-friendly computer systems? A critical examination of the concept. Behaviour and Information Technology, 2(1), 3-16.

Stewart, T. F. M. (1976). Displays and the software interface. Applied Ergonomics, 7(3), 137-146.

Strub, M. H. (1975). Automated aids to on-line tactical data inputting (Technical Paper 262). U.S. Army Research Institute for the Behavioral and Social Sciences. (NTIS AD A010 350)

Strub, M. H. (1971). Evaluator of man-computer input techniques for military information systems (Technical Research Note 226). Arlington, VA: U.S. Army Behavior and Systems Research Laboratory. (NTIS AD 730 315)

Tainsh, M. A. (1982). On man-computer dialogues with alpha-numeric status displays for Naval command systems. Ergonomics, 25(8), 683-703.

Thimbleby, H. (1978). Dialogue determination. International Journal of Man-Machine Studies, 10(6), 651-668.

Thomas, J. C. (1976, February). Quantifiers and question-asking (Research Report RC 5866). Yorktown Heights, NY: IBM, Thomas J. Watson Research Center.

Thomas, J. C., Jr. (1978). A design-interpretation analysis of natural English with applications to man-computer interaction. International Journal of Man-Machine Studies, 10, 651-668.

Thomas, J. C., Jr., & Carroll, J. M. (1981). Human factors in communications. IBM Systems Journal, 20(2), 237-263.

Thomas, J. C., & Gould, J. D. (1974, November). A psychological study of query by example (Technical Report RC 5124). Yorktown Heights, NY: IBM, Thomas J. Watson Research Center. (Also AFIP Conference Proceedings, 1975, 44, 439-445.)

Thompson, D. A. (1971). Interface design for an interactive information retrieval system: A literature survey and a research system description. Journal of the American Society for Information Science, 22, 361-373.

Tomeski, E. A., & Lazarus, H. (1975). People-oriented computer systems. New York: Van Nostrand Reinhold Co.

Treu, S. (1982). Uniformity in user-computer interaction languages: A compromise solution. International Journal of Man-Machine Studies, 16(2), 183-210.

Tullis, T. S. (1981). An evaluation of alphanumeric, graphic, and color information displays. Human Factors, 23, 541-550.

Uber, G. T., Williams, P. E., & Hisey, B. L. (1968). The organization and formatting of hierarchical displays for the on-line input of data. AFIP Conference Proceedings, 33, 219-226.

Van Muylwijk, B., Vander Veer, G., and Waern, Y. (1983). On the implications of user variability in open systems. Behaviour and Information Technology, 2(4), 313-326.

Waltz, D. L. (1976). Natural language access to a large data base. Computers and People, 25, 19-26.

Wasserman, A. I. (1973). The design of 'idiot-proof' interactive programs. AFIP Conference Proceedings, 42, M34-M38.

Waterman, D. A., Anderson, R. H., Hayes-Roth, F., Klahr, P., Martin, G., & Rosenschein, S. J. (1979, May). Design of a rule-oriented system for implementing expertise (N-1158-1-ARPA). Santa Monica, CA: Rand Corp.

Waterman, D. A., & Jenkins, B. M. (1977, March). Heuristic modeling using rule-based computer systems (p-5811). Santa Monica, CA: Rand Corp.

Weizenbaum, J. (1966). ELIZA-a computer program for the study of natural language communication between man and machine. Communications of the ACM, 9(1), 36-45.

Wheeler, T., & Innocent, P. (1983). Human factors in and requirements of the OSI environment. Behaviour and Information Technology, 2(4), 335-344.

Williams, D. H. (1981). Designing hardware and software for mere humans. In Warren, J. C. (Ed.), The best of the computer fairs: Volume VI (pp. 457-463). Woodside, CA: Computer Fair.

Williams, T. J. (Ed.) (1977, January). Guidelines for the design of man/machine interfaces for process control. West Lafayette, IN: Purdue University. (NTIS AD A036 457)

Williges, B. H., & Williges, R. C. (1982, January). User considerations in computer-based information systems (revised) (Technical Report CSIE-81-2). Blacksburg, VA: Virginia Polytechnic Institute and State University.

Williges, R. C., & Williges, B. H. (1982). Modeling the human operator in computer-based data entry. Human Factors, 24(3), 285-299.

Wohl, J. G. (1982). Information automation and the Apollo program: A retrospective. IEEE Transactions on Systems, Man and Cybernetics, SMC-12(4), 469-478.

Wong, P. C. S. (1983). MMI: The man-machine interface. Training Technology Journal, 1(1), 19-35.

Zloof, M. M. (1977). Query-by-example: A data base language. IBM Systems Journal, 16(4), 324-343.

U.S. GOVERNMENT PRINTING OFFICE 1985 - 646-006/

END

FILMED

2-86

DTIC